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The Pollen Required by a Colony of Honeybees

J. E. Eckert, *University of California, Davis*

Bees cannot rear brood without pollen. Langstroth made this statement in his book "On the Hive and the Honeybee," in 1853. Dzierzon many years previously had expressed the opinion that bees were able to furnish food for their young without the presence of pollen in the hive but only for a short time and at great expense of vital energy. The blind naturalist Huber was the first to prove definitely that pollen was essential to the production of brood. This was done about the year 1800 in order to disprove the theory that pollen was used in the production of wax.

More recently, various experiments have been made to determine the amount of pollen required to produce the brood of bees or to find some substitute that could be fed to bees to maintain brood-rearing when natural sources were not available. The results of these researches were reviewed briefly by Todd (1940). The amount of pollen estimated as necessary for normal brood-rearing in a colony was listed at 45.76, 66.22, and 88 pounds per year, depending on the method of computation. Todd further reported the collection of pollen in traps placed before hives in four different locations in California with the full year's trappings varying from 29.7 to 39.6 pounds.

The amount of honey a colony of bees is able to produce depends, for the most part, on the strength of the colony, the nectar available within flying range of the honeybee, and weather conditions that prevail during the flowering period of the nectar-producing plants. It is now well known that the strength of the colony depends to a large extent on the amount of pollen and honey in the hive from which the bees can rear brood some six to eight weeks prior to the nectar flow. The colony cannot live without honey and cannot rear brood to any practical extent without pollen. So while honey is essential to the life of the adult bees, pollen is a vital factor in prolonging the life of the colony. That the colony can live for a considerable time on honey alone is an easily demonstrated fact. It is, however, not known just how important pollen is in the diet of the adult bee if we exclude brood-producing activities. Haydak (1935) has shown that the nitrogen content of newly emerged bees is lower than after bees of the same generation have had time to consume some pollen, and that normally a very significant increase in the nitrogen content of the head takes place between the third and fourth days after emergence. The nitrogen content of the bodies of workers decreased after they became engaged in field activities and gradually approached that of the newly emerged bee. It is therefore, not clear whether the nitrogen increase soon after emergence was essential to the life of the adult bee or incidental to the development of the brood food glands and the production of the constituents of royal jelly.

Betts (1928) emphasized that pollen is indispensable to brood-rearing, stating that pollen contained not only vitamins but also proteid substances essential to growth, both of which are either lacking in honey or present only in minute quantities.

Securing Pollen Records.—The pollen records given in the graph resulted from the collection of pollen in traps, as described by Todd (1940), placed before the entrances of normal colonies. The use of four traps, similarly constructed, revealed a lack of uniformity in the spacing of the wires in the commercial stock of galvanized wire as well as an evident difference in the average size of bees in different colonies. These conditions caused an uncontrollable variation in the pollen trap results out of all proportion to the actual activities in gathering pollen. The

traps always disorganized the work of colonies for a number of days after being placed in front of their entrances, so much so that the pollen collected during these periods of disorganization could not be considered as the typical amount of pollen a normal colony would have collected during the same period. It was also observed that the average colony strength would be reduced after a few weeks to a point where it could not be considered normal. This condition resulted from a reduction in brood-rearing as well as from physical impairment of the field bees as they forced their way through the wires of the trap. For these reasons it was found necessary to use at least two traps and to change them at different intervals whenever the work of the colony appeared to become abnormal. While the weights of pollen were recorded each evening from the individual traps, only the weights of pollen collected by a colony after it had reoriented its activities to a trap were used in compiling a daily record of the work or a normal colony for the season. While the record appears as the production of a single, normal colony, it actually is made up of the production of a number of colonies, each contributing for short periods during the season. The trap was left on some colonies longer than others as it was found unnecessary to change the traps at regular intervals. Thus, in 1940, the seasonal record was made up of the periodic collections of seven colonies with the period of the colony being recorded varying from 1 to 14 weeks. In 1941, eight colonies were used with the intervals of use varying from 4 days to 13 weeks.

Periodic examination of the trap-colonies indicated that in most cases brood-rearing was reduced and the amount of food material in the larval cells became markedly low. Those colonies that remained normal for longer intervals were able to carry small loads of pollen through the wire mesh of the entrance screen. For this reason, the total amounts listed in the graph cannot be considered the total amount of pollen collected. That this amount might have been considerable was evident because certain colonies were able to maintain brood-rearing in as many as 10 frames for some weeks after their original supply of pollen was used up. In such colonies deposits of fresh pollen could be found in the brood area. In 1941, the trap was left on the last colony from July 17 to the close of the records on October 20, with the exception of 4 days when the trap was removed to another colony. During this time, the colony gathered 57.64 pounds of pollen, fresh weight. Near the close of this period, the queen was superseded, although she was not old. Considerable fresh pollen was found in scattered areas in the brood chamber.

THE SIGNIFICANCE OF POLLEN RECORDS.—An identification of the various types of pollens collected in the traps will indicate not only the plants from which the bees secure the pollen, but also the relative importance of each plant as a pollen producer under the conditions that prevail at the time the collections are made. That all colonies do not work on the same source of supply in a given locality is immediately evident by an examination of each day's harvest from the different traps. A greater variety of pollen plants was visited in the spring and during the summer than during the period of the main honey flow from yellow star thistle, *Centaurea solstitialis* L., as this plant is also an excellent pollen source.

A pollen curve will indicate the potential value for brood-rearing of a given territory during the different periods of the year and since the strength of a colony is directly related to the amount of pollen stored during the brood-rearing season, the pollen curve would aid in determining the potential strength of a colony at any particular period.

A record of the actual amount of pollen a single colony collects during even a short period where an abundance of pollen is available, demonstrates in a very concrete manner the activities of bees as pollenizing agents.

THE PROBABLE AMOUNT OF POLLEN USED BY A COLONY.—During the past 10 years we have never found any normal colony with a pollen-clogged brood chamber in the apiary in which the accompanying records were taken. It is evident, therefore, that the average annual consumption of pollen of a normal colony in this area must approximate the total number of pounds represented by the records shown in the graph. The colonies do not normally rear brood during the winter period in this area even though they may have a plentiful supply of pollen in their combs. The spring periods are often cool

and unfavorable for bee flight at a time when the colonies are rearing brood heavily and during such times large stores of pollen are depleted rapidly. A surplus of pollen gathered during the spring period is also used up during a scarcity of pollen in May, June and early July.

The total amount of pollen recorded in the composite record of 1940 from the middle of February to the last of October was 122.24 pounds, while in 1941, the composite total for a normal colony was 111.67 pounds from March 5 to October 20. That both years were favorable for bee activity, as well as plant growth, is indicated further by the records of the scale hives in honey production. The total net gain of the scale colony in 1940 was 257.9 pounds and in 1941, 251.0 pounds. The same strains of bees were used and similar manipulative practices employed in both years.

The chemical composition of pollen from different sources varies widely and the relative value of any given pollen in the rearing of brood is as yet unknown but can be determined by accurate feeding tests, hence the total number of pounds of pollen collected in any given locality may not be a true index of the actual food value to brood-rearing of the pollens collected. The total amount of pollen essential to the greatest efficiency of a colony will also vary with the activities of the bees performing useful work, such as in pollination, in the production of surplus bees for the package bee trade, or in the production of honey and beeswax. The presence of large stores of pollen in a colony may even be undesirable if the bees continue to rear brood and consume large amounts of honey in so doing.

SUMMARY.—In determining the amount of pollen a normal colony of bees might collect during an active season, it was found necessary to change the pollen traps to different colonies at intervals and to allow time for each colony to reorient itself to the pollen trap. Due to the evident variation in the size of bees in different colonies, a given trap with a fixed size of wire mesh was more efficient on some colonies than on others. The total amount of pollen collected in the traps was not the total amount gathered by the bees because a considerable amount of pollen was carried through the trap into the hive, sufficient to maintain brood-rearing on a reduced scale. Therefore, trap records are not 100 per cent accurate.

The total amount of pollen used by the average normal colony in the apiary in which the records were taken was at least equal to and conceivably greater than the amount recorded for a normal colony. The amount of pollen recorded in 1940 was 122.24 pounds and in 1941, 111.67 pounds per normal colony. Since pollens from different sources vary in chemical composition, the relative food value of a given pollen would have to be considered, along with the amount available, in determining the potential worth of a known pollen plant to a colony.—1-6-42.

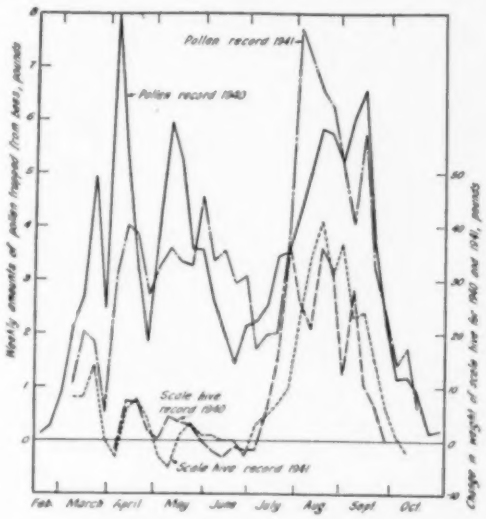

FIG. 1.—The amount of pollen collected by a normal colony during weekly intervals in 1940 and 1941, and the total change in weight of a colony on scales during the same periods.

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The Composition of Pollens[1]

FRANK E. TODD, and ORMOND BRETHERICK,[2] *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

The apicultural interest in the constituents of pollen is twofold: First, as the chief source of the protein, minerals, and special biological products in the honeybee diet, and its part in the determination of the brood-rearing cycle; second, in relation to its possibilities as a surplus apiary product, like honey and beeswax. It is estimated that a tonnage comparable to that of honey (80,000 tons per year) could be produced in the United States if a market were available. The nature of such a market is dependent on the chemical composition of pollens. Preliminary work on the determination of the constituents of pollen from specific plant sources is reported in this paper.

REVIEW OF LITERATURE.—The analyses of many pollens for specific materials are found in the literature, but relatively complete analyses are found for only 13 pollens from specific sources. Nine of these pollens were hand-collected. *Pinus silvestris* pollen was analyzed by Von Planta (1886), Kressling (1891), Elser & Ganzmüller (1931), and Kiesel (1922); *Campanula medium* and *Picea exelsa* by Elser (1928); *Corylus avellana* by Von Planta (1885) and Elser & Ganzmüller (1931); sugar beet, *Beta vulgaris*, by Stift (1901); ragweed, *Ambrosia artemisifolia*, by Heyl (1917) and Koessler (1918); rye (Roggen) by Kamman (1904); alder (*Alnus*) by Elser & Ganzmüller (1931); and corn by Anderson & Kulp (1923). Elser (1928) also analyzed bee loads of pollen from dandelion *Taraxacum officinalis*, horsechestnut, *Aesculus hippocastanum*, Gramineae, *Anthriscus vulgaris*, *P. silvestris*, and two unknown sources. The analyses of both the hand- and bee-collected pollens show that in general pollen from various plant species has a wide range in protein (7.9 to 40.0 per cent), fat (1.50 to 23.6 per cent), ash (2.8 to 10.6 per cent), and sugar values, and most pollens are low in starch (0.8 to 11.1 per cent). Undetermined matter, after removal of water, ether extract, protein, sugars, starch, and ash, made up from 33.5 to 57.9 per cent of the pollen samples.

The analyses of pine pollens by various workers are in substantial agreement, showing low reducing sugars (0 to 1.61 per cent), approximately 6 to 12 per cent sucrose, 7 per cent starch, 12.6 to 16.6 per cent protein, 2.8 to 5.5 per cent ash, and 10 to 14.6 per cent fats. The pine pollens analyzed in the present investigation appear to agree with those in protein, sugars, and ash, but show lower values for fats and starch. Elser's bee-collected pine pollen was higher in fats (6.22 per cent) and showed a high sucrose content (29.76 per cent). The latter is probably due to his use of fresh material, while our material had been air-dried and inversion of sucrose could have taken place. His undetermined matter was 5.66 per cent, while ours for lodgepole pine was 34.26 per cent. Analyses of pine by the other investigators showed large percentages of undetermined matter.

The bee-load dandelion pollen analyzed by Elser was, like ours, comparatively low in protein, but high in fats, and contained little sucrose. His undetermined matter was 13.86 per cent while ours was 27.64 per cent.

The analysis of hand-collected pollen from yellow dent corn by Anderson & Kulp (1923) is comparable to our results for protein and ash, but showed lower values for starch and fats. They reported higher starch values for white flint, 19.04 per cent, and popcorn, 18.03 per cent, which approximate those found in this study. Their undetermined matter was 29.80 per cent, while ours was 30.98 per cent.

The ash of *Pinus*, *Alnus*, and *Corylus avellana* pollen was analyzed for certain minerals by Elser (1931), and corn by Anderson & Kulp (1923). These analyses showed, in order of abundance, potassium, phosphorus, calcium, and iron. Anderson & Kulp also found magnesium and chlorine present in corn but Elser found neither of these in his samples.

The most complete analysis of any pollen was made by Heyl (1917, 1919,

[1] A contribution from the Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture, in cooperation with the University of California.

[2] Resigned March 5, 1939.

1920, 1922, 1923), in which he isolated 27 well-defined organic substances from the various fractions of ragweed pollen.

METHODS.—Pollen samples, each weighing 100 grams, were collected by two methods. From six plants yielding copious pollen the material was collected by hand. These samples were in powdery form. The remaining samples were collected in traps placed on honeybee colonies, and were in the form of pellets as brought to the hive by the bees. Each pellet consists of innumerable pollen grains from a single plant species stuck together with nectar or honey, but pellets from many different plant species were found in the traps. From these conglomerate samples the pellets were sorted by comparing them as to color and grain morphology with characteristic pellets collected by bees from known plants. The purity of samples obtained in this manner may be open to question, regardless of the constancy as to species of pollen load. Pollen collected on the same date at the same trap was kept together.

The analytical work was done under the direction of the late C. S. Bisson then head of the Division of Chemistry, University of California, Davis, by standard methods. All weights and analyses calculated are on a crude air-dry basis.

Table 1.—Description of pollen samples[1]

No.	Plant Source	Locality (California Except As Noted)	Date 1938	Pellet Color
1	Mustard (charlock), *Brassica kaber*	Winters	Mar. 29	Dirty yellow
2	Common mustard, *Brassica campestris*	Orange	Mar. 15	Dirty yellow
3	Blue gum, *Eucalyptus globulus*	Orange	Jan.	Gray
4	Peach, *Prunus persica*	Winters	Mar. 29	Brownish
5	Monterey pine, *Pinus radiata*	Davis	Mar. 29	Sulfur yellow
6	Redmaids, *Calandrinia ciliata*	Winters	Mar. 29	Orange, oily
7	Almond, *Prunus communis*	Davis	Mar. 3	Light green
8	Black willow, *Salix nigra*	Woodlake	Apr. 28	Bright yellow
9	Buckthorn, *Ceanothus crassifolius*	Black Star Canyon	Feb. 21	Yellow
10	Mixed	Black Star Canyon	Mar. 7	—
11	Digger pine, *Pinis sabiniana*	Placerville	May 8	Sulfur yellow
12	Black walnut, *Juglans nigra*	Winters	May	Dark yellow
13	Asparagus, *Asparagus officinalis*	Courtland	June 3	Salmon pink
14	Milk thistle, *Silybum marianum*	Davis	May 28–30	Purple
15	Olive, *Olea europaea*	Davis	May 25	Yellow
16	Chamebatia, *Chamaebatia foliolosa*	Placerville	July	Red orange
17	Black oak, *Quercus kelloggii*	Paynes Creek	May 7–11	Yellow
18	Dandelion, *Taraxacum vulgare*	Mineral	June 9–13	Orange, oily
19	Willow, *Salix* sp.	Mineral	June 9–13	Bright yellow
20	Clover, *Trifolium* sp.	Courtland	June 6–13	Dark Brown
21	Birch brush, *Ceanothus integerrimus*	Paynes Creek	June 18	Yellow
22	Lodgepole pine, *Pinus contorta*	Mineral	June 18–24	White
23	Cattail, *Typha latifolia*	Courtland	June	Yellow
24	Black mustard, *Brassica nigra*	Glenn	May	Dirty yellow
25	Clover (ladino), *Trifolium repens*	Glenn	May	Dark brown
27	Date palm, *Phoenix dactylifera*	Scottsdale, Ariz.	April	Brown
28	Corn, *Zea mays*	Wisconsin	Aug. 1937	Light yellow, grainy
29	Mixed (willow predominant)	Baton Rouge, La.	Spring	—
30	Legume (native)	Mineral	July 6	Dark green, large grain
31	St. Johnswort, *Hypericum perforatum*	Placerville	June 1–17	Golden
32	Star-thistle, *Centaurea solstitialis*	Davis	Aug. 22–24	Dirty yellow
33	Bermuda grass, *Cynodon dactylon*	Orange	Aug. 13–15	White
34	Uredospores	Mineral	September	Red

[1] All samples except numbers 5, 11, 12, 23, 27, and 28 were collected from the bees.

DESCRIPTION OF SAMPLES.—A description of the 34 samples is shown in table 1. The samples included representatives of 17 plant families. The anemophilous, or wind-pollinated, types are represented by date palm, pines, oak, walnut, cattail, corn, and bermuda grass; the others are of insect-pollinated type. All the hand-collected and two of the bee-collected pollens were from anemophilous plants. Bees have been observed collecting from all the plants listed except cattail, and most of the species are important sources of pollen for honeybees in California. The pellets

ranged in color from brown, gray, and white to include all the spectral colors except blue. Sample 34 was gathered in large quantity by bees at Mineral, Calif., in September when no other source was available. It was later found to be, not pollen, but the spores of red rust fungus on the leaves of the native cottonwood, *Populus trichocarpa*, and on willows *Salix* sp.

The crude protein, ether extract, carbohydrates, water, and ash values of the pollens described in table 1 are shown in table 2.

Table 2.—Analyses of pollens. (Samples collected by each method arranged in order of increasing protein content.)

Sample No.	Protein	Ether Extract	Carbohydrates[1]	Water	Ash	Undetermined
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
			Hand-collected:			
11	11.36	2.73	13.15	14.08	2.59	56.09
5	13.45	1.80	13.92	11.25	2.35	57.23
23	18.83	1.28	31.93	6.43	3.82	37.71
28	20.32	3.67	36.59	5.53	2.55	31.34
12	23.15	17.55	13.72	3.91	3.07	38.60
27	35.50	3.08	1.20	17.14	6.36	36.72
			Bee-collected:			
22	7.02	2.04	48.35	7.01	1.32	34.26
18	11.12	14.44	34.93	10.96	0.91	27.64
30	14.85	2.81	33.99	12.84	2.50	33.01
19	15.38	5.25	41.92	13.61	2.19	21.65
15	16.71	4.69	35.78	10.12	1.90	30.80
6	16.75	5.66	38.87	9.06	2.68	26.98
17	19.13	6.56	37.25	11.49	1.98	23.59
14	19.97	7.63	27.82	15.35	1.95	27.29
33	20.44	2.37	29.33	13.34	3.06	31.46
20	20.68	3.22	30.21	13.44	5.49	26.96
32	21.19	6.56	24.88	16.23	1.80	29.34
24	21.74	8.58	25.83	13.22	2.54	28.09
8	22.33	4.15	32.18	12.30	2.61	26.43
1	22.41	13.13	28.92	9.75	2.57	23.22
29	23.26	4.39	32.08	8.23	2.96	29.08
16	23.36	4.24	30.45	15.68	2.60	23.67
25	23.71	3.40	26.89	11.56	3.14	31.30
2	25.29	9.61	24.69	9.99	2.79	27.63
13	25.60	4.05	26.03	10.74	4.36	29.22
21	26.08	0.94	24.54	10.07	3.11	35.46
3	26.22	1.38	29.96	9.09	2.71	30.64
4	26.48	2.71	32.44	8.47	2.81	27.09
10	26.48	4.05	20.50	9.48	3.62	35.87
31	26.90	2.85	30.37	11.10	3.04	25.74
7	28.06	3.13	28.29	9.79	2.62	27.49
9	29.87	1.21	29.22	8.09	3.11	28.50
			Fungus spores:			
34	9.10	1.33	25.71	15.39	2.15	46.32

[1] Sugars and starch. See table 3.

CRUDE PROTEIN.—Protein is the most important constituent of pollen from the standpoint of the honeybee colony. The analyses show that bee-collected pollens have a wide range in protein values, 7.02 to 29.87 per cent, with a mean of 21.60 per cent. Eight of these pollens were below 20 per cent and nine above 25 per cent in protein. Contrary to Lidforss' (1899) conclusion, in our series pollen from anemophilous plants as a group was not greatly different in protein value from that from entomophilous plants.

In crude protein pollens compare favorably with seed and grain feed-stuffs (Titus 1939), being comparable with alfalfa-leaf meal (20.4 per cent), coconut meal (20.5 per cent). flaxseed (22.3 per cent), and navy beans (22.7 per cent), but they are below most of the feed of animal origin (meat scraps, tankage, etc.).

We have little knowledge of the protein requirements of bees or of the nutritive value of pollen. It should be remembered that the protein value is no index to nutritive value. For example, dandelion (No. 18) is considered to be a valuable brood-rearing pollen, although it is comparatively low in protein; while blue gum (No. 3), not so highly valued, is above the average in protein content. Bees rear brood with uredospores (No. 34), which have a low protein value, but reserves of this material may go unused when pollens are available.

ETHER EXTRACT.—The ether extract of the bee-collected pollen shows a rather wide range of values, 0.94 to 14.44 per cent, with a mean of 4.96 per cent. The highest values are for dandelion (No. 18) and mustards (Nos. 1, 2, and 24), which beekeepers consider outstanding brood producers. This fraction compares favorably, at least in quantity, with the grain and seed feedstuffs (Titus 1939), such as corn (4.2 per cent), wheat bran (4.2 per cent), shorts (4.5 per cent), middlings (4.7 per cent), and soybean meal (5.5 per cent). Aside from fats, ether extract may contain certain vitamins, pigments, waxes, oils, and resins. Growth-stimulating hormones have also been found in this fraction (Mitchell & Whitehead 1941). Until it is further broken down, we have little knowledge of its constituents for comparison with other products.

CARBOHYDRATES.—The carbohydrate group includes such substances as sugar, starch, gums, and celluloses, but in this work examination was made for only reducing sugars, nonreducing sugars, and starch. The relative amounts of reducing and nonreducing sugars and starch are shown in table 3. Reducing sugars were found in all the bee-collected pollens, in amounts ranging from 18.82 to 41.21 per

cent, with a mean of 25.71 per cent. Very little nonreducing sugar (2.71 per cent) was found in the bee-collected samples, three samples showing none. The reverse was shown in the hand-collected pollens.

Casteel (1912) showed that in the case of corn pollen the collecting bee added a fluid which increased the reducing-sugar content. A comparison of bee- and hand-collected pollen from the lodgepole pine (Nos. 22 and 22A) showed a large increase in the reducing sugars in the bee-collected pollen, and also indicated that approximately two-thirds of the nonreducing sugar had been inverted. Since neither corn nor pine yields nectar, this material was probably honey carried from the hive by the bee and use to stick the grains together to facilitate carrying.[1]

Corn pollen (No. 28) had a high starch content (22.40 per cent), and the pollens from cattail (No. 23, 13.01 per cent) and willow (No. 19, 10.61 per cent) were considerably higher than the mean for the bee-collected samples (2.55 per cent). On the whole, starch cannot be considered an important ingredient of pollens gathered by bees.

WATER.—Bee-collected pollen pellets are soft when freshly collected, but were found to lose about 20 per cent of their weight and become hard when dried in the air. In most cases the binding material is water-soluble, as the pellets break up when soaked in water. Elser (1928) states that horsechestnut pollen is gathered without the addition of honey, but he found the water content of this pollen to be similar to that of dandelion. The air-dried bee-collected pollens had a water range from 7.01 to 16.23 per cent, with a mean of 11.16 per cent. The hand-collected pollen had a wider range, 3.91 to 17.4 per cent, with three of the six samples below the range for the pellets. Water thus makes up a large but variable part of pollen. Moisture content appears to bear no relation to the sugar content of the pellets.

ASH.—The ash content of bee-collected pollens ranged from 0.91 to 6.36 per cent, with a mean of 2.70 per cent, comparing favorably with that of grains and seeds. Samples 13 and 20, showing very high ash content, were both from the Sacramento delta area.

Analyses of the ash for calcium, magnesium, phosphorus, potassium, and iron are given in table 4.

Table 3.—Percentage of sugars and starch in pollens. (Samples collected by each method arranged in order of increasing reducing sugars.)

SAMPLE NO.	REDUCING SUGARS	NON-REDUCING SUGARS	STARCH
	Per cent	*Per cent*	*Per cent*
	Bee-collected:		
10	18.82	0.00	1.68
21	19.58	4.76	0.00
13	20.02	4.63	1.38
20	20.04	2.37	7.80
25	21.42	4.15	1.32
3	21.50	6.50	1.96
32	21.64	2.09	1.15
2	21.73	1.83	1.13
4	21.81	9.00	1.63
24	22.02	1.15	2.66
9	23.50	3.70	2.02
1	23.92	2.79	2.21
7	24.43	3.12	0.74
33	25.53	3.43	0.37
14	26.41	0.25	1.16
31	27.10	3.27	0.00
16	27.69	0.00	2.76
30	28.05	0.00	5.94
29	28.50	1.88	1.70
15	28.93	5.79	1.06
6	29.11	2.67	7.09
8	30.17	0.57	1.44
19	30.70	0.61	10.61
18	32.36	0.58	1.99
17	32.48	2.01	2.76
22	41.21	3.40	3.74
	Hand-collected:		
22A[1]	0.00	10.48	——
23	0.04	18.88	13.01
5	0.05	11.45	2.42
27	1.07	0.13	0.00
28	6.88	7.31	22.40
11	7.50	3.47	2.18
	Fungus spores:		
34	23.85	1.08	0.78

[1] Hand-collected lodgepole pine pollen.

The mineral content of bee-collected pollen should be viewed with caution because of the opportunity for contamination through dust in the air, soil, sprays, and so forth. It may be significant, however, that no great differences occur between hand- and bee-collected material, either in the average amount of ash or in its composition. In this connection an

[1] Cotton-pollen grains are coated with a viscid material which sticks them together, but nectar collectors transfer them to the corbiculae only with difficulty and pollen gathering from this source is rare.

Table 4.—Analyses of the ash content of pollens. Per cent of ash constituents in pollen.

Sample No.	Potassium	Phosphorus	Calcium	Magnesium	Iron
	Per Cent	*Per Cent*	*Per Cent*	*Per Cent*	*Per Cent*
			Bee-collected:		
18	0.13	0.05	0.26	0.20	0.0009
22	.28	.11	.03	.13	.0006
32	.33	.27	.31	.13	.0014
14	.34	.23	.30	.19	.0013
15	.35	.33	.20	.17	.0024
30	.38	.22	.72	.23	.0044
19	.42	.28	.20	.06	.0011
8	.43	.58	.20	.17	.0015
24	.44	.39	.36	.23	.0016
17	.46	.25	.17	.16	.0010
13	.52	.28	.44	.29	.0071
21	.55	.27	.62	.26	.0011
10	.57	.65	.24	.18	.0026
16	.59	.18	.33	.20	.0014
7	.62	.54	.11	.15	.0018
9	.63	.66	.28	.11	.0016
2	.63	.60	.30	.20	.0015
29	.66	.36	.36	.22	.0016
25	.66	.37	.37	.20	.0029
3	.68	.49	.17	.09	.0026
31	.68	.59	.32	.17	.0018
33	.69	.22	.43	.25	.0012
4	.73	.57	.19	.13	.0019
1	.79	.54	.14	.20	.0014
6	.95	.26	.12	.06	.0017
20	1.11	.36	.24	.35	.0042
			Hand-collected:		
12	.54	.61	.13	.18	.0031
28	.67	.26	.10	.21	.0015
11	.87	.36	.04	.09	.0010
5	.88	.30	.03	.11	.0015
23	.97	.49	.30	.24	.0038
27	1.14	.71	1.18	.38	.0036
			Fungus spores:		
34	.65	.16	.32	.20	.0010

analysis by Aronssohn (1911) of the ash of old drones is of interest for comparison with the values found for pollen ash:

Table 5.—Comparison of analyses of the ash of old drones with that of pollen.

	Ash of Old Drones[1]	Pollen Ash[2]
	Per cent	*Per cent*
Phosphorus	22.5	13.6
Magnesium	2.3	6.7
Calcium	1.3	10.5
Potassium	0.5	20.7
Iron	0.3	0.07

[1] Calculated from Aronssohn's (1911) figures.
[2] Calculated from data in table 4.

Undetermined Material.—A striking feature of the analysis was the consistently high percentage of undetermined matter, after removal of water, ash, ether extract, protein, sugars, and starch. It ranged from 21.65 per cent to 35.87 per cent in the bee-collected material, with a mean of 28.55 per cent, and up to 57.23 per cent in the hand-collected material. We suspect that much of this material is in the shell of the pollen grain, which is resistant to digestive processes and weathering, and is so tough that grinding is difficult. In view of the demand for plastics, use might be found for such a material.

Pigments.—A striking characteristic of pollen is the variety of colors displayed. While no specific work was done on these pigments, they were observed to be of both water-soluble and fat-soluble types. When placed in sugar sirup or nectar, some pollens imparted colors indistinguishable from the greens and ambers found in honey. Bisson, *et al.* (1940) found the yellow color of beeswax to be due to the fat-soluble pigments of pollen.

Summary.—The composition of pollen is of interest not only as a bee food, but as a possible apiary product. It is estimated that the bee industry could produce 80,000 tons of pollen per year if a market were available.

Samples of pollen from 32 plant species and one uredospore were analyzed, 6 of which were hand-collected and 27 bee-collected.

Pollen composition varies widely, showing the following mean percentages for bee-collected samples: Crude protein 21.60, ether extract 4.96, water 11.19, ash 2.70, reducing sugar 25.71, nonreducing sugar 2.71, starch 2.55, and undetermined matter 28.55.

Pollen ash showed the following average values: Potassium 20.7, phosphorus 13.6, calcium 10.5, magnesium 6.7, and iron 0.07 per cent.

In food materials pollen compares favorably in crude protein with alfalfa-leaf meal, coconut meal, flaxseed, and navy beans; in ether extract with corn, bran, shorts, middlings, and soybean meal; and in ash with grain and seeds.—1-6-42.

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Various Kinds of Soybean Flour as Pollen Substitutes[1,2]

M. H. HAYDAK and M. C. TANQUARY, *University Farm, St. Paul, Minn.*

It has been established (Haydak 1940) that soybean flour mixed with skim milk powder in proportion 4:1 by weight is a satisfactory pollen substitute for bees. There are a number of brands of soybean flour on the market, and these differ in their chemical composition, due to different processes used in manufacture.

A comparison of four different brands is here presented (SBF, I–IV). In all of these, fat has been extracted by the solvent method, but SBF-I was also heat treated after the oil had been extracted.

The method and the procedure of the experiment did not differ considerably from those described previously (Haydak 1940). Two colonies were used to test each kind of soybean flour.

The results of the experiment are presented in table 1.

Examination of the table shows that as the fat content and the protein efficiency of the food diminish the mortality of the experimental bees increases and the brood rearing capacity decreases. The number of bees reared was also smaller than in the previous experiment (average, 1484, unpublished results), when soybean flour processed by the expeller method was used.

It is probable that with the oil extracted by the solvent from the flour, some other important lipids have also been extracted. Therefore it was decided to increase the

[1] Paper No. 1942 Scientific Journal Series. Minnesota Agricultural Experiment Station, St. Paul.

[2] Grateful acknowledgement is made to Dr. J. W. Hayward of the Archer Daniels Midland Co. of Minneapolis for supplying various brands of soybean flour and their chemical composition and to Mr. H. E. Milliron for technical help during the experiment; also to Mr. C. W. Sievert of the American Dry Milk Institute for supplying the necessary skim milk powder.

Table 1.—Comparative value of four kinds of soybean flour.

Brand	Av. Composition of Soybean Flour			Results of the Experiment		
	Protein per cent	Fat per cent	Protein efficiency per cent[1]	Mortality of bees per cent	Number of sealed cells and larvae before sealing	Indices of food efficiency
SBF-I	51.0	1.5	90–95	27.8	532	5.1
SBF-II	51.0	1.3	90	31.0	409	4.2
SBF-III	48.9	.8	90–90	40.4	200	2.6
SBF-IV	50.1	.8	30	67.7	0	1

[1] Approximate values.

fat content of SBF-I to 5.5 per cent by an addition of the crude oil extract and to repeat the experiment. In order to find out whether an additional increase in the essential lipids would improve the quality of the food still further, 10 per cent of dried egg yolk was added to the enriched food in fat mixture and, in another case, the food was supplemented with raw whipped egg yolk in proportion, two egg yolks to 70 gms. of the dry mixture.

The results of this experiment are presented in table 2.

Table 2.—Results of feeding an enriched flour.

Brand	Mortality	Number of Sealed Cells and Larvae Before Sealing	Indices of Food Efficiency
	Per Cent		
SBF-I Crude oil extract	19.8	621	6.5
SBF-I +fat+dry egg yolk	18.1	1318	10.3
SBF-I +fat+fresh egg yolk	23.9	817	7.5

From table 2 it is evident that an addition of crude oil extract brought about a considerable reduction in the percentage of mortality and an increase in the brood rearing capacity of the experimental bees. An incorporation of dried egg yolk in the diet caused still further improvement. Fresh egg yolk increased the brood rearing capacity of the bees but some of the larvae showed a diseased condition. The latter fact would speak against the use of fresh egg yolk as an addition to soybean flour.

SUMMARY.—Four brands of solvent extracted soybean flour mixed with skim milk powder in proportions 4:1 have been fed to experimental bees. The results showed that with the decrease of the fat content and of the protein efficiency of the food, the mortality of experimental bees increased while their brood rearing capacity decreased. The restoration of the fat content to 5.5 per cent by an addition of the crude oil extract to the most promising brand brought about a decrease in mortality and an improvement in the brood rearing capacity of the bees. An addition of 10 per cent of dried egg yolk to the dry pollen substitute increased the food value of the latter still further. Although an addition of raw egg yolk improved the food value of the diet, a diseased condition which appeared in some larvae would speak against its use as a supplement to pollen substitutes.—1-6-42.

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Royal Jelly and Bee Bread as Sources of Vitamins B_1, B_2, B_6, C, and Nicotinic and Pantothenic Acids[1,2]

MYKOLA H. HAYDAK and LEROY S. PALMER, *University of Minnesota, St. Paul*

In previous communications (Haydak & Palmer 1938, 1940, 1941) the authors presented results of bio-assays of royal jelly for vitamin E and B_1 and of bee bread for vitamin E, B_1, A and riboflavine.

Melampy & Jones (1939) found that royal jelly contains little if any ascorbic acid, but Manuilova (1938) established the ascorbic acid content of bee bread to be from 50.2 to 343.1 mg. per cent, the variation depending on the time of the season the bee bread was taken from the hive.

In the present experiment pyridoxine (vitamin B_6) content of royal jelly and bee bread was investigated, using a biological assay method. The presence of other vitamins in the bee foods has been determined by microbiological or microchemical methods. For the latter determinations the authors are indebted to Mr. A. Earl Vivino.

In the determination of pyridoxine (vitamin B_6) the method of Reedman and coworkers (1940) was used. When the symptoms of deficiency appeared, the rats were given various levels of royal jelly or bee bread and were observed for a period of 14 days. The results of the experiment are presented in Table 1.

Table 1.—Pyridoxine (vitamin B_6) content of royal jelly and bee bread.

Supplement Fed	Amount Fed Daily	Total Rats	No. Cured	No. Partially Cured
Pyridoxine	100	2	2	
	150	1	1	
Royal jelly	5 gm.	4	4	
	3 gm.	2	2	
	2 gm.	1	1	
	1 gm.	3	2	1
	.5 gm.	1		
Bee bread	10 gm.	2	2	
	7 gm.	1	1	
	5 gm.	4		2

[1] Paper No. 1947 Scientific Journal Series. Minnesota Agricultural Experiment Station. St. Paul, Minnesota.

[2] This paper is No. 4 in a series of reports on the "Vitamin Contents of Bee Foods."

From the results of the experiment, it is apparent that royal jelly is almost 10 times as rich in pyridoxine as bee bread. According to Reedman and coworkers, a single dose of 100 micrograms of the pure vitamin is sufficient to effect 100 per cent cures in rats; 50 micrograms will completely cure 70–80 per cent of the animals and cause some improvement in the remaining ones; 25 micrograms will produce some improvement in several animals but few complete cures. From the results of the experiment, it is evident that royal jelly may contain about 50 micrograms of pyridoxine per gram of fresh matter and bee bread only about 5 micrograms.

The results of the microbiological and microchemical methods are presented in table 2. The methods used were: for thiamine, that of Hennessy & Ceresedo (1939); for riboflavine, Snell & Strong (1939); for pyridoxine, Scudi (1941); for ascorbic acid, Bessey (1938); for nicotinic acid, Snell & Wright (1941), and for pantothenic acid, Strong *et al.* (1941).

It is interesting to note that the variations in the composition of royal jelly from year to year were not great, while in bee bread the variations were quite pronounced. This is not surprising because royal jelly is a glandular secretion while bee bread may have been collected by bees from different plants, pollens of which might have varied as to vitamin content.

The results of the microchemical and microbiological investigations are in relatively close accord with those of the biological assay method. Thiamine content of royal jelly and bee bread, according to our earlier results (Haydak and Palmer, 1940), is 3.1 and 4.5 micrograms per gram of fresh matter respectively. Bee bread and royal jelly of the 1939 crop have been used in this experiment. The average riboflavine content of bee breads of 1939–1940 found by the biological assay method (Haydak & Palmer, 1941) was about 20 micrograms per gram of fresh matter. The average found by the microbiologica method shown in table 2 is about 25 micrograms. The ascorbic acid content

Table 2.—Thiamine chloride, riboflavine, pyridoxine, ascorbic acid, nicotinic acid and pantothenic acid content of royal jelly and bee bread.

Bee Food	Thiamine	Riboflavine	Pyridoxine	Ascorbic Acid	Nicotinic Acid	Pantothenic Acid
	micrograms per gram	micrograms per gram	micrograms per gram	milligrams per gram	milligrams per gram	micrograms per gram
Bee bread 1935	3.85	30.3	0	0.118	1.25	0.45
Bee bread 1939	5.02	15.0	0	0.068	0.21	0.175
Bee bread 1940	4.95	34.2	0	0.110	0.06	0.175
Royal jelly 1940	2.91	9.37	0	0.005	0.11	0.68*
Royal jelly 1941	1.46	9.50	0	0.003	0.08	0.75*

* Since this paper was prepared Pearson & Burgin (Proc. Soc. Exp. Biol. Med. 48: 415, 1941) have reported that royal jelly contains on an average 183 micrograms of pantothenic acid per gram of fresh, and 511 micrograms per gram of dry matter. The cause of this result, which is widely different from ours, cannot be explained now.

of royal jelly is insignificant, which is in accord with the results of Melampy & Jones (1939); while the ascorbic acid content of bee bread falls within the limits given by Manuilova (1938).

Chemical determinations did not show even traces of pyridoxine either in the bee or royal jelly, while the biological assay showed that it is present and, in case of the royal jelly, even in sufficient amounts to effect complete cure of acrodynia in reasonable doses.

Summary.—Biological assay on royal jelly and bee bread showed that the former contains about 50 micrograms of pyridoxine (vitamin B_6) per gram of fresh substance and the latter about 5 micrograms. Microbiological and microchemical determinations ascertained the presence of thiamine, riboflavine, ascorbic acid, nicotinic acid and pantothenic acid in both royal jelly and bee bread in various amounts. These variations were greater in bee bread than in royal jelly. The presence of pyridoxine could not be established either in royal jelly or in bee bread by the microchemical method. A table showing the vitamin contents of the royal jelly and the bee bread is given.—1-6-42.

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Orange Nectar and Pollen in Relation to Bee Activity.[1]

GEO. H. VANSELL and WM. G. WATKINS, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine* and ROY K. BISHOP, *Office of Agricultural Commissioner, Orange County, Calif.*

A study of orange blossoms in relation to bee activity was conducted in southern California during April of 1939, 1940, and 1941. Both the Navel and Valencia varieties, growing on light and on heavy soils, were observed as to blossoming habit, nectar secretion, and sugar concentration.

The crop of orange honey varies greatly in size from year to year. It was previously supposed that an alternation between heavy and light bloom was the major cause. Although there is such an alternation, it is evident that not all the trees in a grove or all the groves bloom heavily at the same time. An entire grove or an individual tree will be white while a neighboring one is almost devoid of blossoms. About half the trees appear to be in heavy bloom each season, so there are probably enough blossoms to give a honey crop in southern California each year. Data on the numbers of blossoms on some individual trees, selected for uniformity in size and shape, are presented in table 1.

Table 1.—Blossoms on orange trees during three seasons at Santa Ana, Calif.

Variety and Tree No.	Number of Blossoms		
	1939	1940	1941
Valencia:			
1	11,828	7,441	7,300
2	19,657	1,270	12,400
3	2,374	2,384	14,600
4	25,000[1]	2,390	16,250
Washington Navel:			
1	11,512	5,366	5,900
2	901	50,000[1]	1,078
3	9,160	1,247	15,200
4	8,166	3,121	7,050
Buckeye Navel:			
1	30,000[1]	3,306	—[2]

[1] Estimated by averaging fractional counts of three observers.
[2] Not counted, but tree white with blossoms.

The orange blossom is a copious producer of nectar. The nectar glands are large, and consist of a collarlike ring of whitish tissue around the base of the ovary. The life of an individual blossom is only about 1 week, but a succession of a large number of blossoms extends the time of nectar production in commercial quantities to 3 or more weeks. Off-season blossoms contribute their small supply of nectar over a long season. Secretion continues at least 48 hours after the petals unfold. Excessive heat greatly hastens petal shedding and shortens the nectar-secreting period. As the trees are grown under irrigation, a dependable growth is assured each year.

Some of the orange blossoms were nearly full of nectar, containing about 50 microliters, a quantity sufficient for 1.5 bee loads. The sugar concentration of such nectar was low. In the course of extensive hand collection in the groves, about 50 blossoms provided on an average 1 cubic centimeter of nectar, or 20 microliters per blossom. In comparison, alfalfa blossoms in a greenhouse yielded from 0.83 to 2.4 microliters.

The orange is one of the few blossoms that secrete nectar before the petals unfold. The fact that the opening blossoms already contain nectar may be one reason for the characteristically sudden appearance of an orange honey flow. Nectar collected from the mature buds should be of the same sugar concentration as when secreted, unaffected by contact with the air. The sugar concentration of the bud nectar in several widely separated localities during 4 years was found to be within the narrow range of 13 to 17 per cent. The

Table 2.—Sugar concentration of bud nectar for various localities during 4 years.

Year	Locality in California	Variety	Approximate Average Sugar Concentration
			Per cent
1938	Lindsay	Navel	15
1939	Santa Ana	Navel and Valencia	16
1940	Corona	Navel	16
		Valencia	15
1941	Lindsay, Colton, Corona, and Santa Ana	Navel and Valencia	14–16

[1] A contribution from the Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture, in cooperation with the University of California.

average concentrations over this period are shown in table 2.

Upon exposure to the air the nectar is subject to change in water content, and unless the fresh, thin orange nectar is evaporated into a richer solution, it is not very attractive to bees. Especially is this true in the presence of the more concentrated mustard nectar, which averages about 50 per cent sugar in various parts of California as well as in Oregon and Utah.

The influence of humidity on the sugar concentration of nectar from various types of blossoms has been pointed out by Park (1929). Many of the orange groves in southern California are not far from the ocean and fogs are common. An occasional sample of orange-blossom nectar collected during a low-humidity period in 1940 contained 40 per cent sugar, but the average for all the samples was about 34 per cent. On the other hand, during a foggy, humid season, such as that of 1939, the average concentration of the orange nectar was about 20 per cent. Bees were then practically absent from the blossoms, although an occasional individual appeared hurriedly to sample the nectar in the blossoms. Nectar was sufficiently abundant to drop from the blossoms when the twigs were gently shaken.

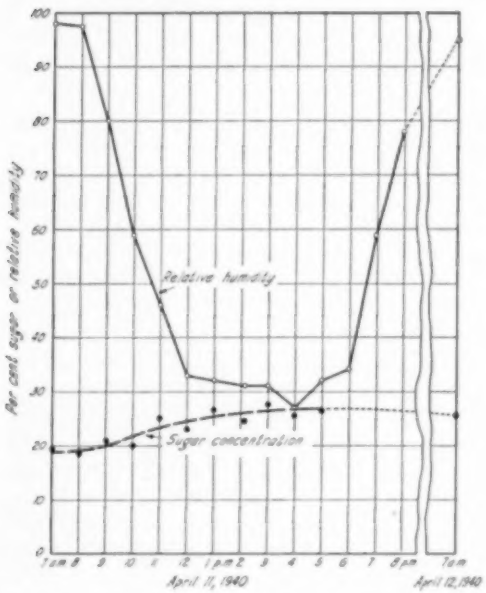

FIG. 1.—Changes in relative humidity and in the sugar concentrations of orange-blossom nectar during a calm day.

High humidity at night, in the absence of fog, did not appreciably dilute the nectar, for samples exposed in the blossoms or in shallow watch glasses under the trees changed but slightly, if at all, during the night. In the periods of fairly humid, calm weather in 1939 and 1940, the nectar concentration in the open blossoms increased somewhat during daylight hours, remained constant at night, and then increased to a slightly higher concentration the following day, and so on. The changes in relative humidity and sugar concentration during a calm day in 1940 are shown in figure 1.

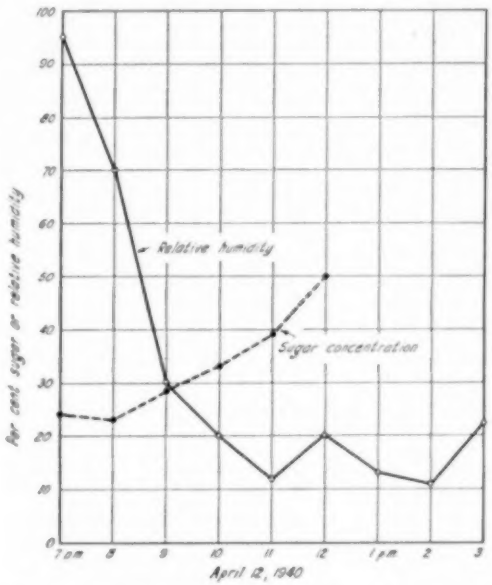

FIG. 2.—Change in relative humidity and in the sugar concentration of orange-blossom nectar during a dry windy day.

On the other hand, during a day with high and then low humidity, in 1940, and a dry east breeze beginning at 8 a.m., the concentration changed rapidly from about 25 per cent to 50 per cent by noon. The relation between relative humidity and sugar concentration for this day, when evaporation was high, is shown in figure 2. Whenever the concentration approached or exceeded 30 per cent, bees were actively collecting the nectar. Some of the bees coming into the hive carried nectar of 50 per cent sugar concentration. The scale hive during this day increased 22 pounds

in weight. Since there were about 30,000 colonies on this flow, the amount of orange honey stored on this one day must have been very large, perhaps 300 tons. On the following two days weather conditions were similar, but thereafter a humid ocean wind reversed the evaporation conditions and no colony gains were recorded for a few days. Orange nectar was still abundant, but it was not then attractive to bees.

Table 3.—Average sugar concentration in buds, in fresh and old blossoms, and in honey bees on the blossoms, 9:30 a.m., April 9, 1941, at Santa Ana, Calif.

SOURCE OF NECTAR	AVERAGE SUGAR CONCENTRATION
	Per cent
Closed buds	13.8
Buds with 1 or 2 petals open	15.7
Recently opened blossoms	20.3
Old shattering blossoms	30.8
Honeybee stomachs	31.9

It is evident that the sugar concentration of nectars within flight range of the apiary influences bee activity greatly. Not only do species and varieties compete for bee visitation but also the same kind of blossoms of various ages, for in 1941 bees were observed selecting the older orange blossoms, which contained the richer nectar. The sugar concentration of nectar in orange blossoms of various ages and in the bee stomach is shown in table 3. The same bee response to sugar concentration has been observed in deciduous fruit orchards.[2]

[2] Vansell, Geo. H. 1942. Nectar and pollen gathering by honeybees and other insects. U. S. Dept. Agr. Circ. (Submitted for publication.)

During two seasons samples of hand-collected orange nectar were submitted for analysis at the University of California. The data given in table 4 show that the total sugar ranged from 19.80 to

Table 4.—Analyses[1] of orange-blossom nectar for sugar content.

YEAR	VARIETY OF ORANGE	SUCROSE	DEXTROSE	LEVULOSE	TOTAL SUGARS
		Per cent	*Per cent*	*Per cent*	*Per cent*
1939	Valencia and Navel	9.10	6.32	4.38	19.80
1940	Navel	12.87	5.42	7.46	25.75
	Valencia	12.38	5.06	6.08	23.52
Average		11.45	5.60	5.97	23.02

[1] Analyses in 1939 were made by D. R. Hoagland, of Berkeley, and those in 1940 by H. G. Reiber and H. W. Allinger, of Davis, Calif.

25.75 per cent. The sucrose content was about double that of either of the invert sugars. Chemical analyses of orange nectar reported by Alin Callais (1926), of France, gave the sugar as 26 per cent.

The Valencia orange produces pollen but the Navel does not. The hand-collected nectar from the Valencia blossoms contained about 24,000 pollen grains per cubic centimeter, while that from Navel blossoms had none. In comparison with the pollen loads from mustard, the size of the Valencia pollen loads, as brought to the hive on the bee legs, is small, but this variety contributes its share of the total supply available in the various orange-honey-producing locations during blossoming time.—1-19-42.

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DR. ARANT COMMISSIONED IN THE SANITARY CORPS

Dr. F. S. Arant, Associate Entomologist of the Alabama Agricultural Experiment Station, Auburn, has been granted leave of absence for the duration of the war and has accepted a commission as a Captain in the Sanitary Corps.

Captain Arant is, at this writing, stationed at the Lawson General Hospital, Atlanta, Georgia.

Bee Poisoning in Washington[1]

R. L. Webster, *Washington Agricultural Experiment Station, Pullman*

Years ago beekeepers in the irrigated valleys of eastern Washington were forced to seek new locations because of the heavy spray program necessary to control the codling moth in the apple orchards of that region. This was especially true in the Yakima valley, where many diversified crops are grown. In consequence, a large area known as the Reservation, formerly Indian land, south of the city of Yakima and westward from Wapato and Toppenish offered some relief from bee poisoning because few orchards had been planted and because of rather large plantings of alfalfa and an abundance of sweet clover. Yards in the vicinity of Wapato and Toppenish, however, continued to suffer and these are within bee flight of sprayed orchards, although the concentration of orchards is far less in that vicinity than it is only a few miles to the eastward.

Reported Poisoning in Potato Fields.—In 1933 it became necessary for the first time to use arsenicals to spray for the Colorado potato beetle, which previously had attracted little attention. At the same time beekeepers began to complain of heavier losses than usual and it was generally attributed to the use of insecticides on the potato plants. A survey of the damage was made at that time and previously reported (Webster & Crews 1934).

With the advent of the potato flea beetle in the Yakima valley the application of insecticides became even more general and many growers purchased power dusters in order to protect their crops from attack by the new pest. Some beekeepers moved elsewhere in the state while others attempted to find locations sufficiently distant from potato fields to minimize their losses.

In 1940 an opportunity was offered to obtain further information on the dangers involved in keeping bees in an area where extensive dusting operations for flea beetle control were being conducted. This was in Kittitas county, immediately north of Yakima county, an irrigated district in which some 8,500 acres of potatoes were grown at that time and where sprayed orchards were few and far between. Because of the need for more accurate information on the seasonal history of the flea beetles in this area, the Washington Agricultural Experiment Station assigned Harold H. Dodge, a former student in bee culture at Iowa State College, to the problem of flea beetle control as a research fellow. While his main study consisted of making field observations on the flea beetle, he was instructed to observe potato fields carefully for the presence of honey bees.

Commercial beekeeping had assumed considerable proportions in this county because of a large acreage of alfalfa and reports from Yakima county beekeepers who had moved some of their yards into Kittitas county indicated that no losses from bee poisoning were encountered in the new location. Mr. Dodge was located in Kittitas county from early in June until early in October during 1940, and was out in the field practically every day, but reported that the only honey bees observed in potato fields were those working on stray alfalfa or sweet clover plants in search of nectar. No complaints of poisoning came from beekeepers whose yards were within easy reach of dusted fields.

Most of the dust applied was a mixture of cryolite and rotenone, using diatomaceous earth as a carrier. Some 133,760 pounds of this dust was mixed at a plant located in the eastern portion of the irrigated area. Observations of this kind threw considerable doubt as to the source of the poisoning in Yakima county.

Further observations were made in Yakima county in 1941 and reported by Louis J. Lipovsky, assigned to flea beetle work for the summer months in cooperation with the U. S. Bureau of Entomology and Plant Quarantine. Here again honey bees were practically non-existent in potato fields in observations which often began around daybreak when dusting experiments were undertaken in the field.

In Yakima county for the season of 1941 the two materials most used for

[1] Published as Scientific Paper No. 515, College of Agriculture and Agricultural Experiment Station, State College of Washington.

flea beetle control were cryolite dust and a dust containing rotenone. Upon inquiry from supply dealers these were used in approximately equal amounts—one about as often as the other. Next in rank was calcium arsenate, but evidently far less than the two first named materials. Fourth in use came the rotenone-cryolite dust as used in Kittitas county.

On July 10 and again on July 13, 1941 the writer made a visit to Yakima county bee yards, in company with C. F. Branniger, bee inspector for that area. While no heavy losses to colonies were observed numerous workers were seen attempting to take flight from grass or weeds some yards in front of the hives and exhibiting symptoms of poisoning. Most of these yards were within bee flight of sprayed orchards although the locations generally were out of the ordinary range of flight. One yard, the bees owned by W. C. Wixom, formerly a state bee inspector, was in a location probably ten miles west of Wapato and far enough away to practically eliminate the opportunity of spray poisoning from fruit trees. Here again, however, occasional bees were found struggling to the front of the hive entrances.

OBSERVATIONS IN ASPARAGUS PLANTINGS.—Beekeepers in the vicinity of Sunnyside have complained of severe losses in August when asparagus plantings are frequently sprayed with calcium arsenate to kill the second brood larvae of the asparagus beetles. Spraying asparagus with arsenicals generally is delayed until after cutting has ceased and the plants allowed to grow up. There has been some use of rotenone dust early in the season. Asparagus serves as an excellent source of pollen when allowed to flower following the cutting season.

Observations on the activity of honey bees in an asparagus planting were made on the grounds of the Irrigation Branch Experiment Station at Prosser during 1940–41. At the end of the first season it appeared that the peak of honey bee activity preceded that of asparagus beetles by nearly four weeks and that bee population dwindled in an asparagus planting to a point where relatively few bees were present before there was any very great increase in asparagus beetle population. (Fig. 1).

As a basis for comparison the number of honey bees on 10 crowns, each observed for a period of 2 minutes, was recorded to serve as a measure of bee activity. Abundance of asparagus beetles was indicated by recording the number of beetles collected by sweeping with an insect net every eighth row in an 80-row planting. The rows were 110 feet long and approximately 55 sweeps were made for a row. The figures for the honey bees and asparagus beetles are not directly comparable, and must be considered as independent of each other.

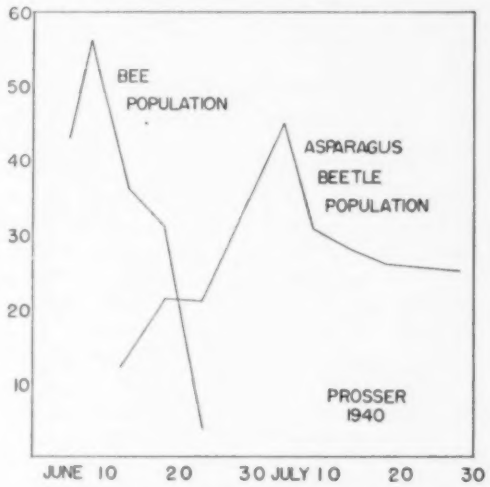

FIG. 1.—Bee population and asparagus beetle population: Prosser, 1940.

Records in 1940 were made by Norton S. Wilson, a graduate student in entomology, detailed to the branch station at Prosser for the summer months to make observations on the asparagus beetle and other insects. The following year similar observations were taken at Prosser by Fred A. Kirsch, also a graduate student.

Cutting from this planting continued until a later date in 1941 as compared to 1940. In consequence bloom was deferred and pollen available until early in July. The peak of bee activity in 1941 came June 30, as compared to June 8, in 1940. (Fig. 2). At the same time the asparagus beetle population increased tremendously necessitating treatment with calcium arsenate, which had not been needed in 1940.

While the peak of the asparagus beetle population was reached on the same date in 1941 as compared to 1940, the peaks for honey bees are some distance apart.

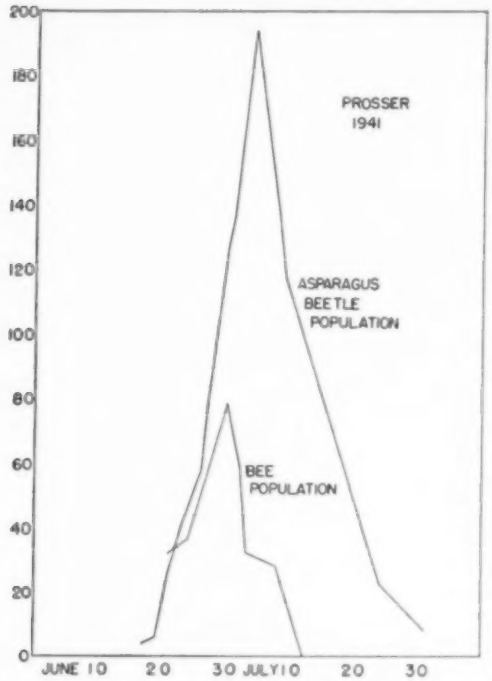

FIG. 2.—Bee population and asparagus beetle population: Prosser, 1941.

Two factors are responsible for the difference in bee activity in the two years: (1) the time at which cutting ceased, (2) the time when the main honey flow from sweet clover and alfalfa began.

It is evident that any arsenical applied to an asparagus planting at the time when bees are frequenting the field will result in killing many bees. On the other hand, it would have been possible in 1940 to make an application of calcium arsenate around June 20 in ample time to control asparagus beetles but at a time when there was very little bee activity in the planting. It may be possible to defer the application of the insecticide to control the asparagus beetle until there is very little danger of poisoning bees.

SUMMARY.—Observations in potato fields in Kittitas county, Washington, in 1940, where many commercial bee yards are located within easy bee flight of potato fields dusted several times with a cryolite-rotenone dust, failed to reveal any honey bees frequenting the potato foliage and no reported cases of bee poisoning. Similar observations in Yakima county in 1941 also failed to show the presence of bees in the potato fields although some evidence of bee poisoning was observed in July, probably from sprayed fruit trees although in one case the bees were quite isolated from sprayed trees.

On an asparagus planting at Prosser, Washington, in 1940, honey bees ceased working on asparagus blossoms for pollen about June 20, when the main honey flow started and at a time when the asparagus beetle population began to rise and spraying for the beetles was opportune. In 1941, however, cutting the asparagus continued until a later date. Asparagus bloom furnished pollen until July 1 and bee activity almost coincided with that of the asparagus beetles.

Honey bee activity in an asparagus planting evidently depends on two factors: (1) the time when pollen is available and (2) the date of the main honey flow.—1-6-42.

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DR. HAWKINS RETIRES

Dr. Lon A. Hawkins, Chief of the Division of Control Operations in the Bureau of Entomology and Plant Quarantine, retired on June 3, 1942. Dr. Hawkins had been a member of the Bureau for 35 years and had served as Chief of his division since its inception. Dr. C. P. Clausen will assume charge of the Division for the time being, in addition to retaining his other duties as Chief of the Division of Foreign Insect Parasite Introduction.

DR. FRACKER COORDINATOR OF RESEARCH

Dr. Stanley B. Fracker, formerly Chief of the Division of Plant Disease Control of the Bureau of Entomology and Plant Quarantine, has recently been appointed Coordinator of Research in the field of Entomology and Plant Pathology.

Dr. James Francis Martin has been appointed Chief of the Division of Plant Disease Control to replace Dr. Fracker in that capacity.

The Mechanism of Colony Resistance to American Foulbrood[1]

A. W. Woodrow and E. C. Holst, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

One of the principal problems of investigations in American foulbrood resistance is the evaluation of resistance of colonies so that the proper breeding stock may be selected. No exact measure of resistance has been available, because the means by which certain colonies are able to withstand or overcome the disease has not been understood. Resistance has been considered to be present in a colony if the disease fails to appear or if it finally disappears after the colony has been inoculated with a more or less controlled quantity of infectious material. It has been attributed either to physiological resistance inherent in the larva, or to behavior of the adult bees in removing diseased material from the comb, or to a combination of the two.

Previous Results.—It has been shown previously (Woodrow 1941a) that larvae of resistant colonies are fully as susceptible to the disease as are those of nonresistant colonies. The only variation is associated with the age of the larvae rather than with their source. The larvae are most susceptible in the first day of larval life. Susceptibility decreases thereafter to the extent that larvae inoculated more than 2 days and 5 hours after hatching are immune.

In view of the lack of variation in resistance in larvae of different strains, colony resistance must be due largely to the behavior of the adult bees either in feeding the larvae or in disposing of the infectious material. Behavior studies already reported (Woodrow 1941b) show that diseased brood remains were readily removed by the bees in both susceptible and resistant colonies. It was found that the time required for removing this material was proportional to the amount of diseased brood present. Cells containing diseased brood later produced healthy brood after they had been cleaned out by the bees. In these experiments, and in others as well, the chances for recovery were closely related to the number of cells of diseased brood found in the colonies. In other words, recovery depended to a considerable degree on the extent of the infection.

Controlled Inoculation of Larvae.—Following this study of behavior a method was developed for the controlled inoculation of individual larvae in the comb without causing general contamination of the colony. This method, which will be described in detail elsewhere, consists of adding, by means of a microsyringe, spores of *Bacillus larvae* in water suspension to the food of larvae within 1 day after they hatch. The larvae are then returned to the colony for feeding and sealing. After all the larvae are sealed, the comb containing them is caged in wire cloth so that the adult bees cannot obscure the results by removing brood as it dies of disease.

Over 30,000 individual larvae have been inoculated. They were obtained from and reared in a large number of colonies of various degrees of resistance. This method of inoculation always produced disease if the brood was properly cared for, irrespective of whether the larvae were obtained from or reared in susceptible or resistant colonies. The source of the brood or the resistance of the colony rearing it had no observable influence on disease development in the larvae themselves. Some brood was removed by the bees previous to sealing time, and in combs not caged removal was greatly increased in the sealed stage.

Brood Removal.—This new method of inoculation was used in measuring the removal of infected brood in three colonies of a highly resistant strain under test in 1940. These colonies contained sister queens, and no disease was found in them following inoculation by the usual method of feeding infectious sugar sirup used in routine testing work. Fifty-five larvae from one colony and 113 from another were individually inoculated and then

[1] A contribution from the Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture, in cooperation with the Agricultural Experiment Stations of Arkansas, Iowa, Texas, Wisconsin, and Wyoming.

returned to their parent colonies for rearing. To show the extent of removal, the combs containing these larvae were not caged during the sealed stage. At emergence time no disease could be found among the inoculated larvae remaining in the first colony, although the exact number removed was not determined; in the second colony 69 inoculated larvae had been removed and none of those remaining were infected. These results were similar to those obtained in the inoculation of brood from other colonies when caging during the sealed stage was omitted. They show that inoculated larvae are removed before emergence time, although evidence that they are removed because of infection was not obtained until later.

Table 1.—Comparative time of removal from combs of diseased sister larvae reared in a resistant and a susceptible colony.

Days After Inoculation	Number of Larvae Removed by Bees				
	Resistant Colony			Susceptible Colony	
	Uninoculated	Inoculated with water	Inoculated with spores	Uninoculated	Inoculated with spores
1	4	4	11	3	25
2	1	0	1	0	5
3	1	2	0	2	1
4	1	1	14	1	9
5	—	—	—	0	5
6	2	2	4	—	—
7	1	0	21	0	10
8	0	0	42	0	6
9	1	1	21	0	1
10	0	0	13	1	7
11	0	0	11	0	7
12	0	0	0	0	3
13	0	0	0	0	6
14	0	0	0	0	5
15	0	0	0	0	1
16	0	0	0	0	39[1]
Total larvae removed:	11	10	138	7	130
Total larvae observed:	101	100	200	100	202

[1] Diseased larvae found in the comb at the final observation, but not actually removed.

Further tests were then made on the brood of the second colony. On consecutive days 102 larvae in one comb and 100 larvae in another were individually inoculated. The first comb was caged while the second was not. At emergence time no diseased brood could be found in the comb not caged, and the inoculated brood in all but four cells had been removed by the bees. In the caged comb 42 inoculated larvae were removed before the brood was sealed and caged and, of the 60 remaining, 45 became diseased.

The third resistant colony was used for individual inoculation work in which comparisons were made with other, more susceptible, colonies. In these comparisons, which included rearing after inoculation in both resistant and susceptible colonies, infection was produced in the brood of this colony as readily as in that of other colonies. These experiments demonstrate that disease is readily produced in the brood of resistant colonies and that it is removed by the bees so rapidly that it may never be observed. They also show that resistance is not due to behavior of the adult bees in feeding the larvae.

REMOVAL AND RESISTANCE.—The early removal of diseased brood in these resistant colonies indicated that the time of removal was important in colony resistance. If the bees removed the dead brood before *Bacillus larvae* had reached the spore stage, and if the larvae were not susceptible to *B. larvae* in the rod stage, as Tarr (1937) found to be the case, the spread of disease in a hive would be halted. To determine if the larvae could be infected by the rod stage of *B. larvae*, 603 larvae in 5 combs were inoculated with heavy suspensions of rods removed from fresh cultures. Only 3 larvae became diseased. They may have become infected by spores remaining in the suspensions, although no spores could be detected microscopically. Apparently *B. larvae* in the rod stage is noninfective.

Table 2.—Microscopic diagnosis of daily samples taken from inoculated sister larvae partially removed from combs in a resistant and a susceptible colony.

Days After Inoculation	Resistant Colony			Susceptible Colony		
	Larvae sampled	Larvae infected	Larvae containing spores	Larvae sampled	Larvae infected	Larvae containing spores
6	4	—	—	0	0	0
7	6	5	0	0	0	0
8	8	7	0	0	0	0
9	3	3	0	7	6	2
10	8	8	0	4	3	2
11	0	0	0	4	4	3
12	0	0	0	4	3	3
13	0	0	0	6	5	5
14	0	0	0	1	1	1
15	0	0	0	—	—	—
16	0	0	0	15	15	15[1]

[1] Only 1 being removed.

A resistant and a susceptible colony were used to determine the time at which

diseased larvae are removed from the comb. For these tests two combs of brood obtained from the susceptible colony were used, one comb being given to each colony for rearing after larvae within it had been inoculated with 100 spores each. Besides the inoculated larvae both combs contained other larvae, some of which were located but not inoculated to serve as checks. In addition, 100 larvae in the comb placed in the resistant colony were inoculated with sterile, distilled water as a further check on removal. After inoculation the combs were placed in the two colonies, and daily examinations were made, until emergence time, to determine the extent and exact time of brood removal. Whenever larvae partly removed were discovered, smears from them were examined microscopically to determine whether the larvae were infected and whether they contained rods or spores of *Bacillus larvae*.

The number of larvae removed previous to the examination each day is given in table 1, and the results of the microscopic examinations of larvae partly removed are given in table 2. No partly removed larvae were found in the resisttant colony until the sixth day, and in the susceptible colony until the ninth day. It has been found, however, that rods of *Bacillus larvae* are present in successfully inoculated larvae as early as 24 hours after inoculation. Since removal among larvae inoculated with water was no greater than among those not inoculated, the inoculation procedure itself caused little or no removal, and from 7 to 11 per cent of the removal was due to normal mortality.

The bees in the resistant colony removed, within 11 days, 138 of the 200 inoculated larvae given to it and no spores were found in any larvae being removed, although 23 of the 25 examined contained rods. No more infected larvae appeared in this colony and no more were removed after the eleventh day. Inoculated larvae were removed more slowly in the susceptible colony, with removal covering the entire developmental period. At emergence time diseased brood, typical of American foulbrood in appearance, was still present in 39 cells. *Bacillus larvae* spores were found in inoculated larvae being removed in this colony as early as the ninth day after inoculation, and each day thereafter.

The bees are able to detect early stages of infection in the brood more readily than can the human observer. They are able to do this even with sealed larvae. None of the larvae being removed from the resistant colony were discolored or abnormal in appearance. Most of those examined, however, contained rods of *Bacillus larvae*, as shown in table 2. The first discoloration of brood being removed in the susceptible colony was observed on the ninth day after inoculation. Discoloration is readily observed in larvae containing spores.

Previous to removal numerous sealed cells were found uncapped. In the resistant colony such larvae were removed within 24 hours. Smears from 4 of them contained rods of *Bacillus larvae*. In the susceptible colony, however, 7 uncapped larvae were resealed but disease was found in them all later. One of these larvae, uncapped and resealed on the tenth day, remained sealed until the sixteenth day, when it was found to be diseased. The earlier appearance of spores in larvae reared in the susceptible colony unquestionably was due to delayed removal of larvae dying early of disease, rather than to more rapid formation of spores in this colony. The behavior observed in the resistant colony explains what happens in colonies in which no diseased brood can be found following inoculation, and how this halts the spread of disease. The early removal of diseased larvae while they contain only the noninfectious rods of *B. larvae* prevents further dissemination of the disease in the colony, whereas removal of infected brood containing the highly infectious spores results in spread of the disease to other larvae.

The data presented demonstrate that resistance to American foulbrood consists of the colony's ability to detect and remove diseased brood before the causative organism, *Bacillus larvae*, reaches the infectious spore stage.

SUMMARY.—A new method for the controlled inoculation of individual honeybee larvae with spores of *Bacillus larvae* was used in investigating the mechanism of resistance to American foulbrood. Disease was produced in the brood of resistant colonies as readily as in that from

susceptible ones. All diseased brood was removed by the bees of some resistant colonies before ordinary symptoms of the disease were manifest. In a resistant colony no diseased brood remained long enough to permit the disease organisms to reach the spore stage, whereas in a susceptible colony spore formation occurred in numerous infected larvae. *B. larvae* in the rod stage was found to be noninfective. The data show that resistance to American foulbrood in the honeybee colony consists in its ability to detect and remove diseased brood before the causative organism, *B. larvae*, reaches the infectious spore stage in the diseased larvae.—1-7-42.

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Some Observations on Oil Deposit

HUGH KNIGHT, *Claremont, California*

The question of oil deposit from commercial spray-oil emulsions has engaged the attention of many workers. The early mayonnaise emulsions were quite stable with globules of oil of the order 1–10 microns in diameter and these released probably not more than 10 per cent of their oil content upon application. Then came the quick-breaking emulsion first introduced by this writer in 1924 and produced in the spray tank by the addition of small amounts of emulsifying agent to the water phase. This type of spray later came to be known as "tank-mix;" it gave up between 30 and 40 per cent of its oil content to the sprayed surface and thus allowed the concentration of oil in the dilute spray to be greatly reduced. Later on, about 1930, "emulsible" oils came into use. These were oils in which a small amount of oil-soluble emulsifying agent had been incorporated; these also deposited about 30 per cent of their oil content. A photomicrograph of a typical quick-breaking emulsion of the emulsible type is shown in figure 1 a.

The employment of suitable electrolytes, especially in the water phase, produces marked changes in the emulsion and greatly increases the oil-deposit. Figure 1, b and c, (darkfield) shows the change that occurs; the globules are uniformly enlarged and evened up in size and they become charged and form clusters, leaving clear water between. This is commonly referred to as "flocculation," an incorrect term since no true floc is formed. There is nothing "wool-like" in these clusters of oil globules, as the photomicrographs show, although a superficial observation of them without the aid of the microscope might give an impression of flocculation. Evidently a more accurate term is needed to describe this effect. These oil globules are applied in clusters or bunches, but break instantaneously with the oil adhering to the surface, leaving clear water in the drip. There is no sign of inversion here for the clusters are easily dispersed in the spray tank with ordinary agitation and there is no tendency toward stickiness. This type of emulsion gives up about 60 per cent of its oil content and is the next step in increasing oil deposition.

If the amount of electrolyte is increased, a further change in the emulsion takes place, as seen in figure 2. The globules commence to elongate; they become distorted and assume grotesque shapes. The beginning of the process is shown in "A" where globules are seen coalescing and elongating. The process is shown further advanced in "B". The emulsion is in a state of unstable equilibrium; it is commencing to "invert" but has not yet begun to "stick," and is at the point of greatest oil deposit (approximately 70 per cent) and consequently of greatest efficiency. "c" and "d" show the same thing

with direct illumination. Unless checked at this point complete inversion rapidly ensues (Fig. 3, c and d). In this condition the phases are reversed, hence inverted.

In a dilute oil-in-water emulsion a relatively small amount of oil is dispersed throughout a relatively large quantity of water, *e.g.*, 2 gallons of oil to 100 gallons of water. In a water-in-oil, or inverted emulsion, conditions are reversed, a relatively small quantity of water is dispersed throughout a relatively large quantity of oil. Inversion means a change of phase, or a reversal of the phases so that which was once inside is now outside.

When inversion takes place in the case of a dilute oil-in-water emulsion, the inverted emulsion with oil as the continuous phase can obviously utilize only a very small portion of the total amount of water in the spray tank since the dispersed phase is always less in amount than the continuous phase. This inverted emulsion coagu-

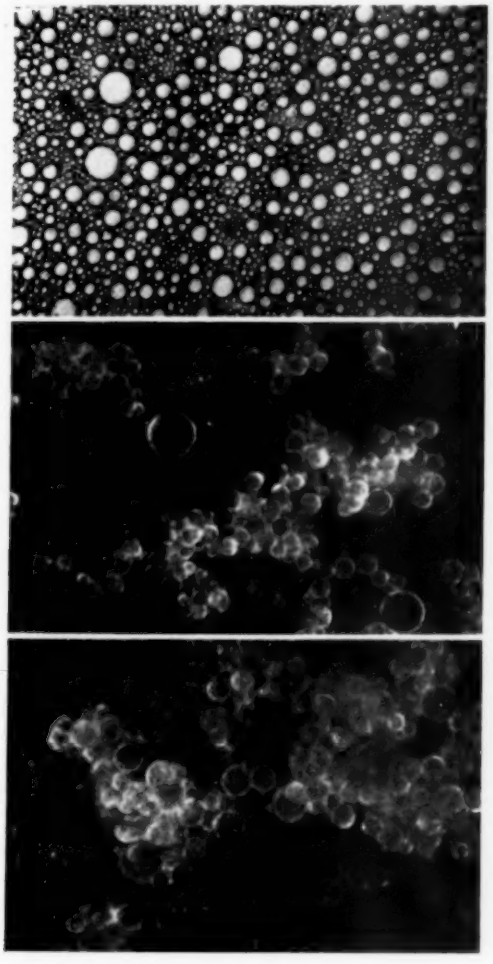


FIG. 1.—*a*. Typical quick-breaking emulsion. *b-c*. Showing oil globules forming clusters after addition of electrolyte, leaving clear water between. Dark-field.

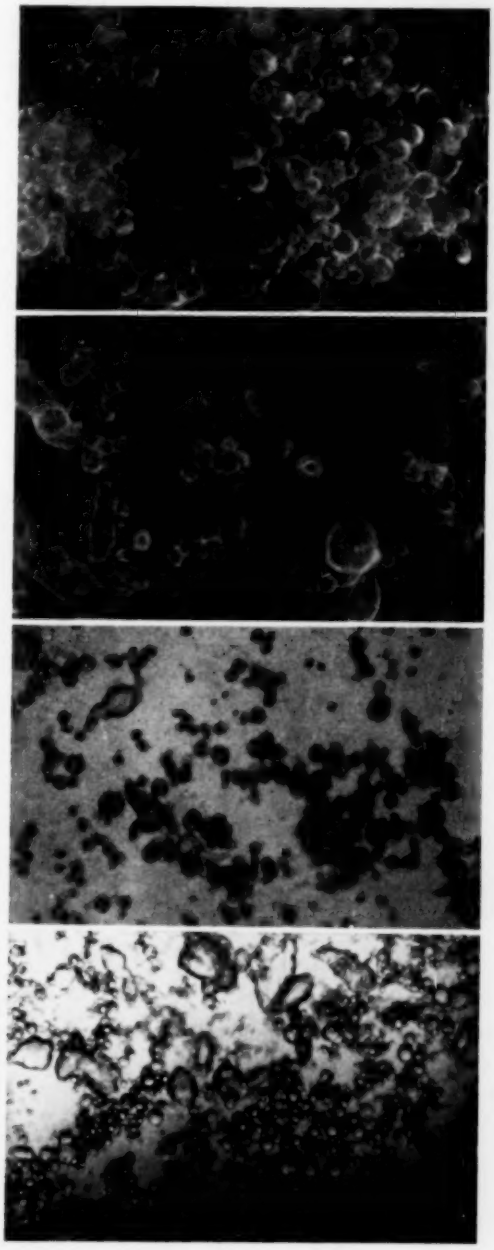
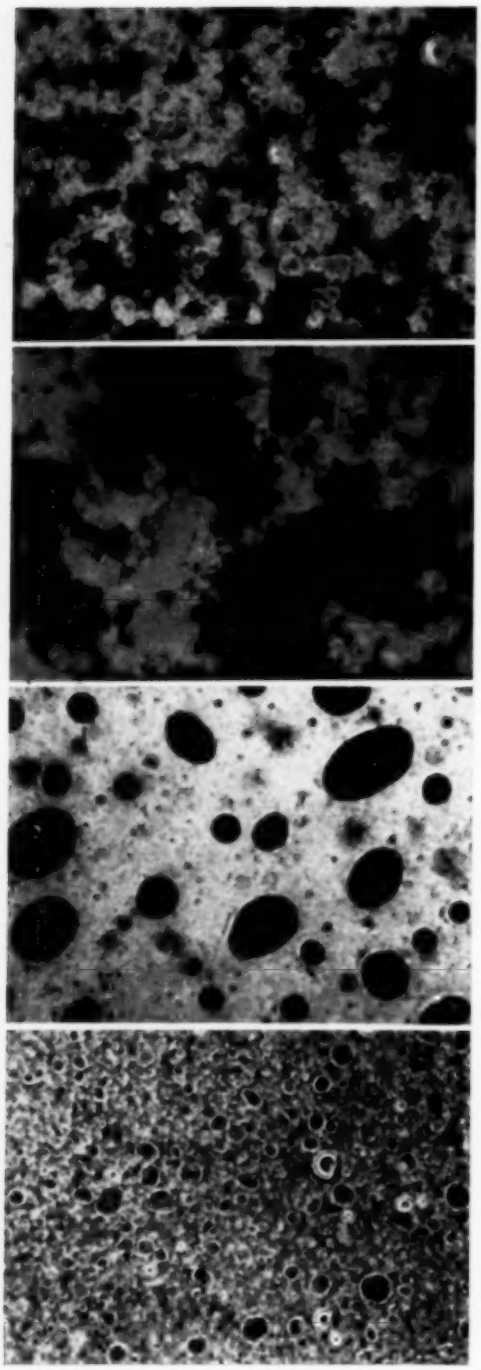


FIG. 2.—*a*. Globules beginning to coalesce and elongate. *b-c-d*. Process of inversion under way. State of unstable equilibrium and highest deposit. Dispersion still possible in spray tank.



lates and rises to the surface as a curdled mass with a consistency varying from that of a thick paint to that of axle grease. This can no longer be dispersed, but sticks to everything it touches, clogs the hose, pump and valves as well as the nozzles and cannot be used for spraying purposes. The only thing left to do is to empty the tank and clean it out, usually with much profanity. This is what is meant by those workers when the laconic term "stuck" is employed in their reports.

The process is essentially the same whether or not a solid suspensoid is dispersed throughout the water phase of the emulsion. For example, when lead arsenate is suspended in the water phase and certain electrolytes are added, the solid suspensoid leaves the water phase and becomes preferentially wet by oil. Figure 3, A and B, shows this process. The lead arsenate is seen here leaving the water for the oil and being taken in and absorbed by the clusters of oil globules, the water between being clear. Inversion has not yet taken place and the lead-oil agglomerates can still be dispersed without trouble. In this condition the oil-lead combination will build up a heavy and continuous paint-like film on both fruit and foliage, the amount of which can be varied at will depending upon the amount of time used in spraying. As in the previous instance, however, if and when actual inversion takes place "sticking" commences and the tank must be emptied.

The term "inverted mixture" is a misnomer and is misleading. It is difficult to understand how a "mixture" of anything can become "inverted" unless two immiscible liquid phases are involved, in which case it is not a mixture but an emulsion. If an emulsion becomes inverted it cannot be applied as a spray, hence the term "inverted emulsion" applied to spray is also a misnomer.—1-6-42.

FIG. 3.—*a-b.* Showing arsenate of lead in suspension leaving the water phase and becoming preferentially wet by oil,—being taken up by the oil clusters. *c-d.* Inversion complete, showing water as dispersed phase of emulsion. This cannot be dispersed spray, tank.

The Determination of Kerosene Oil Deposit on Citrus Leaves[1,5]

FRANCIS A. GUNTHER[2] and WALTER EBELING[3,4] *University of California Citrus Experiment Station, Riverside*

A rapid, accurate, and reproducible method for the determination of the quantity of petroleum oil deposited on the leaves, bark, and fruit of a citrus tree by various spray emulsions is extremely important in investigations involving the use of petroleum oils as insecticides and as carriers for toxic substances. Many factors affect the amount of oil deposited by a spray including added solutes. In order to evaluate a particular toxicant dispersed or dissolved in oil, it is imperative to correlate with the insecticidal data the quantitative estimations of the oil deposited. Differences in the results obtained by using various oil sprays may be due to variations in the amount of oil deposited rather than to differences in the toxicities of the oils used. Unless these variations can be ascertained quantitatively, it becomes impossible to correlate acurately the amount of deposited oil with the factors of toxicity to the insects and injury to the tree. A slight change in the physical or chemical properties of the emulsion may affect the results, and the consequent interpretations, very markedly (Hensill & Hoskins 1935; Ben-Amotz & Hoskins 1937; Brown & Hoskins 1939; McCall & Kagy 1940).

The various gravimetric methods proposed for the determination of the amount of oil deposited on leaves by spray emulsions have been reviewed by McCall & Kagy (1940). In addition, these workers have proposed a colorimetric method involving a primary extraction of the oil from the citrus leaves with an odorless kerosene, the oil being colored with the oil-soluble dye Sudan III before application as a spray. Because of the need for a more rapid laboratory method, Ebeling (1940a) has suggested blotting or preferential absorption as a means of removing the oil from the upper surface of the leaf. The successful application of both these methods has been dependent upon the rapid removal of the deposited oil before it has penetrated into the leaf tissue. Experience in this laboratory has shown that all the petroleum oil in citrus leaves can be removed only with great difficulty once it has penetrated the outer layers of cells.

Rohrbaugh (1934) has proposed a modification of the English (1930) method for purifying and measuring the petroleum spray oil extracted from citrus tissues. In this method the twigs and leaves are dried, ground to a powder, and extracted with petroleum ether. After removal of the solvent, the residue is sulfonated in Babcock milk-test bottles in the usual manner (Tihenko & Hensill 1937).

Pearce *et al.* (1941) have described a method for determining the amount of petroleum oil deposited on apple bark by dormant sprays. Twig samples from sprayed trees are submitted to a continuous extraction process with petroleum ether. After the removal of the solvent, the residue is weighed and a correction factor is applied for the amount of extract that would have been obtained from the twigs had they been unsprayed. In this method the probable error for a single determination is reported to be about 5 per cent.

When petroleum oil penetrates citrus foliage and fruits, it becomes located inter- and intracellularly, and for this reason all methods have failed to remove the oil quantitatively. The more volatile oils, kerosene in particular, penetrate and dissipate rapidly. It is the writer's belief that no adequate, dependable method for determining the *total* amount of an oil deposited on any portion of the tree, including that which has penetrated into the plant tissue, has been proposed.

These considerations led to the conclusion that a method involving the selective chemical disintegration of the leaf cells, accompanied by a steam distillation of the

[1] Paper No. 454, University of California Citrus Experiment Station, Riverside, California.

[2] Laboratory Assistant employed through grant furnished by Irvington Varnish and Insulator Company.

[3] Assistant Entomologist in the Experiment Station.

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[5] This paper is the first of a series of studies in the general field of oil deposit determinations.

stable oils present, would be of value. This method has been standardized and has proved to be rapid, accurate, reproducible, and especially applicable to the determination of kerosene deposits, regardless of the extent to which penetration has taken place.

STEAM DISTILLATION.—When two immiscible liquids are heated in one vessel, each exerts its own vapor pressure, irrespective of the presence of the other liquid. As the temperature of the system is raised, the sum of the vapor pressures of the two liquids approaches atmospheric pressure; when this sum is equal to atmospheric pressure, boiling occurs, and the two liquids distill over together. Since the total vapor pressure is independent of the relative amounts of the two liquids present, the temperature of distillation and the composition of the distillate remain constant until one of the liquids is entirely evaporated. In general, the boiling point of the mixture will be lower than that of either constituent. A constant-boiling (azeotropic) system is not probable under the conditions recommended for the process discussed in this paper; this fact is indicated when changes in volume of kerosene plus wax in distillate are plotted against time intervals (Fig. 4).

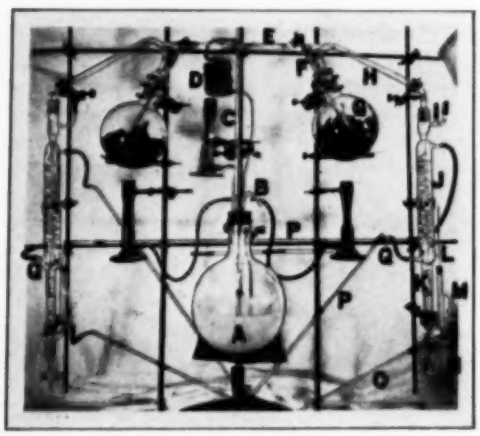

FIG. 1.—Dual-assembly distillation apparatus: A, Pyrex flask; B, refill tube; C, safety tube; D, superheater; E, insulated steam line; F, steam-inlet tube; G, reaction flask; H, steam-exit tube; I, condenser-head side arm; J, spiral condenser; K, receiver; L, thermometer; M, dropping bulb; N, stopcock; O, overflow line; P, condenser water line; Q, vacuum line.

These properties are utilized in the process of steam distillation, whereby a substance practically immisicible with water and having a high boiling point relative to that of water can be distilled quantitatively at a temperature well below its boiling point merely by passing steam through it. By passing superheated steam through a liquid which has a small vapor pressure at 100° C., an unwieldy volume of water as a by-product is avoided, and the rate of distillation is increased.

Paraffin and aromatic hydrocarbons are not dissolved appreciably in water; this fact is evidence that they do not obey Raoult's law. Accordingly, hydrocarbons steam-distill quickly and efficiently. Commercial kerosene is a complex mixture in which paraffin hydrocarbons predominate, but it contains usually a small percentage of unsaturated compounds and some organic compounds of nitrogen, sulfur, and oxygen. Kerosene will therefore steam-distill practically quantitatively.

This method has been applied assiduously to determinations of kerosene deposited on citrus leaves only. Sufficient tests have been made with a light-medium spray oil,[1] however, to indicate that the method is applicable (92 per cent recovery with sulfonation correction), but that higher consistent yields can be obtained with a longer period of total distillation than is used in the recovery of kerosene. The problem of recovering light-medium oils and the heavier spray oils as nearly quantitatively as possible from plant tissues is now under investigation in this laboratory. The problem of recovering kerosene from twigs, bark, and fruit by means of this method is under investigation also.

APPARATUS FOR THIS METHOD.—In order to facilitate the collecting of data, a dual system was assembled, as indicated in figure 1.

A pyrex flask (A) of 5-liter capacity was fitted with a rubber stopper through which passed a refill tube (B), a 5-foot length of safety tube (C), and one end of the copper tubing which constituted the superheater (D). A steam line (E) made of pyrex glass well wrapped with asbestos cord was connected with the steam-inlet tube (F) by means of a short piece of heavy rubber tubing fitted with a Hoffman clamp. This steam-inlet tube extended nearly to the

[1] Fifty-six per cent distillation at 636° F., viscosity 70 seconds Saybolt at 100° F., unsulfonatable residue 90 per cent.

bottom of a 2-liter pyrex flask (G) which was stoppered with a well-rolled cork. The steam-exit tube (H) passed from this flask into the condenser head through another well-rolled cork. A side arm (I) was sealed into the condenser head in order to facilitate the flushing out of the standard 300-millimeter spiral condenser (J) after each distillation without the necessity of loosening the adjacent cork. The receiver (K) was standardized in that it was fitted with a thermometer (L) and a dropping bulb (M), so that both the rate of distillation and the temperature of the distillate could be determined. This receiver contained a piece of calibrated burette tubing cut so that the lower end was sufficiently jagged to allow free flow of liquid between it and the wall of the receiver. The beveled lower tube of the condenser rested against the inner wall of this burette tubing in order to prevent falling drops of distillate from mechanically emulsifying the oil within this inner tube. The oil in the distillate, being lighter than water, remained within the calibrated tube, while the water in the distillate passed through the oil layer and out of the system through the dropping bulb (M). The stopcock (N) permitted the withdrawing of oil samples for sulfonation purposes when the apparatus was being calibrated. An overflow line (O) led from the receiver to the sink. Another line (P) carried water into and out of the condenser jacket. The vacuum line (Q) connected with the laboratory vacuum system served to prevent the liberation of noxious fumes into the laboratory.

This apparatus was practically automatic in operation and allowed the simultaneous running of two samples under identical conditions.

A permanent, all-glass apparatus to allow the simultaneous running of four samples under identical, reproducible conditions is shown in figure 2. This assembly contained no corks or rubber stoppers, with the exception of the ones carrying the refill tube into the steam generator. All joints were standard-taper, and pyrex glass was used throughout the assembly.

LEAF DECOMPOSITION.—Many different solutions were tested as to their efficiency in effecting an adequate disintegration of leaf tissues. The reagent that was found to be most satisfactory was of the following empirical composition: 300 milliliters of technical concentrated sulfuric acid, 11 milliliters of concentrated nitric acid, and 4.5 grams of technical aluminum sulfate made up to 1 liter with distilled water. The sulfuric acid effects the major part of the decomposition, the nitric acid decreases the time necessary for complete decomposition, and the aluminum sulfate both prevents the emulsification of the petroleum oils in the flask and inhibits the frothing of the flask residue near the end of a distillation.

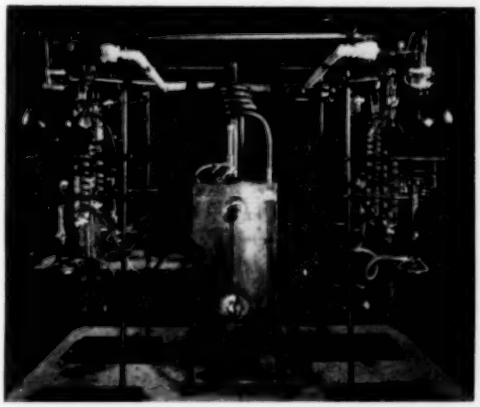

FIG. 2.—Four-unit distillation apparatus. Front view.

A series of 60 runs with known samples was made in order to find a suitable reagent. A known volume of kerosene was painted on the lower surfaces of orange leaves by means of a calibrated microburette. The leaves were allowed to stand 2 hours in a stoppered flask before analysis. The relative proportions of the three reagents were varied over very wide ranges, both in series and in combination. Other electrolytes and other mineral acids were tested in a number of combinations and concentrations, but the results in all cases were less satisfactory than those produced by the reagent described. The composition recommended above is the one that gave the best and most consistent results with varying sample size and with the shortest time of distillation. In the present paper this solution will hereafter be referred to simply as the "reagent." In the laboratory it was found convenient to compound the reagent 20 liters at a time and to measure it out from the storage bottle by means of an automatic dispensing burette.

In all runs with known samples, the kerosene collected in the receiver was transferred quantitatively to Babcock milk-test bottles and sulfonated with concentrated sulfuric acid at 65–70° C. in order to determine the unsulfonatable residue. When the volume of kerosene plus waxes, as read directly in the receiver, was plotted against the volume of the kerosene after sulfonation, a straight line was obtained, as shown in figure 3. This

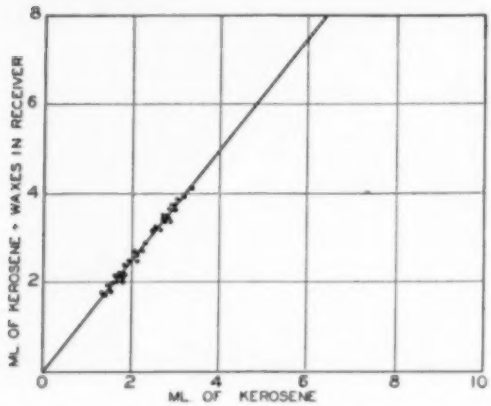

FIG. 3.—Relation between volume of kerosene plus waxes and volume of unsulfonatable residue in distillate.

graph thus shows that sulfonation is unnecessary as a means of determining the unsulfonatable residue of kerosene after the apparatus has been check-calibrated with known samples. The waxy mixtures distilled from three samples of 75 leaves each that contained no applied kerosene sulfonated completely in each instance.

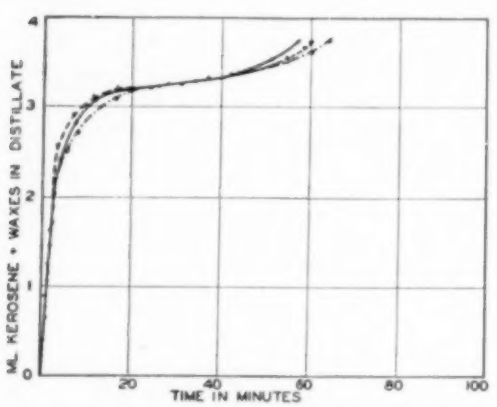

FIG. 4.—Changes in volume of kerosene plus waxes in distillate when plotted against time intervals in three separate experiments.

When the volumes of kerosene plus waxes in the receiver were plotted against time intervals, in three separate experiments, the rate curves shown in figure 4 were obtained. These curves may be interpreted to mean that (1) the distillation is not azeotropic in nature; (2) the major portion of the kerosene distills at the beginning and at the end of the run; (3) in the middle of the run the kerosene distills at a rate which is constant for all three samples shown; and that (4) a very considerable proportion of the kerosene codistills with the plant waxes. This last observation is very significant, for it would seem to indicate that the kerosene inside the leaf tissue (inside the leaf cells) exists *in solution* in the natural waxes and oils of the leaf and not as discrete, homogeneous globules between the cells or within the cells.

ACCURACY OF THE METHOD.—In table 1 are shown the results of seven runs with

Table 1.—Results of tests with four-unit distillation apparatus to determine reproducibility and accuracy of method.

SAMPLE	MILLILITERS OF KEROSENE			PER CENT RECOVERY OF UNSULFONATABLE KEROSENE
	Introduced	Plus Wax in Receiver	After Sulfonation[1]	
1	2.31	2.88	2.30	99.5
2	3.31	4.03	3.25	98.2
3	2.00	2.40	1.99	99.5
4	3.31	4.08	3.28	99.1
5	3.47	4.18	3.38	97.5
6	3.31	3.90	3.16	95.6
7	2.00	2.45	1.99	99.5

[1] The volume of unsulfonatable kerosene is that volume actually determined by sulfonation and not that volume predicted from the graph (Fig. 3).

the four-unit apparatus to determine the reproducibility and accuracy of the method. It will be noticed that sample 6 (Table 1) is the only one in which there is any discrepancy, for the variations among the other runs are so slight as to be insignificant when one considers the probable error introduced in the reading of the burette tubing in the receiver and the known error introduced in the reading of the calibrations on milk-test bottles.

In a field test of this method, leaf samples were picked from an orange grove immediately after the application of a

spray containing 10 per cent kerosene made toxic by the addition of rotenone, with *Cardolite* 627 as a solubilizer (Ebeling 1940b). The results from the five samples taken are shown in table 2.

Table 2.—Results of field test of the method: determination of residue remaining from 10 per cent toxic kerosene spray.[1]

Sample	Number of Leaves	Total Leaf Surface, in Sq. Cm.[2]	Milliliters of Kerosene	
			After Sulfonation	Per Sq. Cm. $\times 10^{4}$
1	74	3,760	2.45	6.52
2	76	3,620	2.85	7.87
3	75	4,050	3.14	7.75
4	75	3,560	2.65	7.45
5	79	3,582	2.45	6.84

[1] The kerosene spray contained a toxic solution of derris extractives, with *Cardolite* 627 as a solubilizer. Four ounces of calcium caseinate spreader was used per 100 gallons of spray, which was applied by means of a 400-gallon power sprayer with 500 pounds pressure and with 0.11-inch disks in the nozzles.
[2] Combined areas of upper and lower surfaces of leaves.
[3] Coefficient of variation, 0.0467.

The coefficient of variation calculated from the data in table 2 is found to be 0.0467, or a variation of 4.67 per cent. It has been the experience of workers at the Citrus Experiment Station that a coefficient of variation of 0.05 indicates a low variability in methods dealing with the removal of spray residues in field experiments.

PROCEDURE.—Within five minutes after spraying, 50, 75, or 100 orange-leaf samples were collected. Average-sized mature leaves (about 25 square centimeters in area) were selected at random from all sides of the trees and placed in 2-quart Mason jars. The jars were capped tightly and stored in the refrigerator at 40° F. The length of time the samples were in storage seemed to make no difference in the amount of recoverable kerosene.

The leaves were removed from the jars one by one, with the fingers or with specimen forceps. Areas were measured by superimposing these leaves upon the outlines of leaves of known area placed under a piece of plate glass. After its area had been measured and recorded, the leaf was placed in the reaction flask. After all the areas of one sample had been measured, any water or kerosene adhering to the fingers, forceps, or glass plate was mopped up with a small piece of filter paper which was also introduced into the flask. This paper was completely digested by the reagent. The liquid adhering to the walls of the Mason jar was removed by adding approximately one-third of the volume of reagent to be used for that sample then capping the jar and shaking it vigorously for a minute or two in order to emulsify the contents as much as possible. The contents were then poured into the flask containing the leaf sample. This operation was repeated until all the reagent had been used to flush out the jar. In these determinations the best results were obtained when 200 milliliters of reagent was used for every 1,500 square centimeters of leaf-surface area (combined area of upper and lower surfaces of the leaves).

The flask was then mounted in the apparatus, and the water in the steam generator was heated to boiling, with the refill tube open to the air. Bumping was prevented by means of several pieces of capillary tubing, sealed at one end, and a small piece of glass wool placed inside the generator. When the steam was issuing freely from the refill tube, it was corked tightly. The burner for the superheater was lighted and adjusted so that the copper coils were a dull red immediately over the top of the burner, and the burner under the reaction flask was lighted and adjusted to give a tall blue cone. The condenser water and the vacuum were then turned on. As soon as the material in the reaction flask had begun to boil, the burner under it was adjusted again so that the rate of distillation was about one and one-half drops per second, as determined by means of the dropping bulb.

The reagent turned yellow; the leaves lost their green color as the chlorophyll was oxidized; and, as the acid became more concentrated, carbonization of the cellulose occurred and the leaves slowly disintegrated. Near the end of the run all the material in the flask became frothy. At this point the flame under the reaction flask was reduced to prevent frothing over into the condenser. Shortly after the appearance of the froth, traces of plant waxes began to condense in the upper coils of the condenser; heating was continued for a period of 25 minutes beyond the appearance of these waxes. During the last 5 minutes the distillation of waxes was very pronounced. At the end of this period the flame under the reaction flask was ex-

tinguished, but steam distillation was continued for an additional 5 minutes. At this point the steam was shut off and the cork in the refill tube removed if all simultaneous runs were completed, an operation preventing the reaction mixture in the flask from being drawn back into the steam line as the system cooled. The kerosene and waxes adhering to the walls of the condenser were flushed into the receiver by pouring three 1-milliliter portions of acetone through the condenser, followed by a total of 10 milliliters of distilled water in several small portions. This volume of water sufficed to "salt out" the acetone dissolved in the kerosene. The volume of kerosene in the receiver was read, and the temperature of the distillate was recorded so that all volumes of kerosene could be recorded at approximately the same temperature.

The condenser and receiver were cleaned for the next run by draining the receiver and flushing the system with acetone or petroleum ether, followed by 50 milliliters of distilled water, through the side arm at the top of the condenser. The reaction flask was cleaned by merely rinsing the nearly liquid residue into the sink. Before starting the next run, the receiver was filled with distilled water to the point of overflow.

If, for the purposes of calibration, the kerosene in the receiver was to be sulfonated after the acetone wash mentioned above, the water in the receiver was separated from the kerosene and discarded, the separation being carried out in the receiver. The kerosene was drained into Babcock milk-test bottles, and that adhering to the walls of the condenser was washed very carefully into a Babcock milk-test bottle by pouring a total of 5 milliliters of petroleum ether through the condenser side arm and the openings of the receiver. After the solvent had been removed *in vacuo*, the kerosene and wax residue was sulfonated in the usual manner.

ERRORS OF THE METHOD.—The only important source of error involved in this method is that incurred if the time of distillation is not standardized. For this reason the writers suggest that every such setup be checked with several known samples, and that these samples be experimentally sulfonated after the distillation in order to ascertain the time of distillation necessary to obtain agreement with the data of figure 3. There will undoubtedly be slight variations in different assemblies built by different persons. The writers have determined empirically that a distillation period of $1\frac{1}{4}$ hours (this includes the time of wax distillation) is sufficient with both of the assemblies described in this paper.

It is apparent that the burette error need not be considered if the graph, or the slope of the line within the graph is used. In order to facilitate the reading of the burette tube in the receiver, however, it was found convenient to place a few drops of a 2 per cent acetone solution of the oil-soluble dye Sudan III into this tube before beginning distillation. This dye imparted an intense red color to the kerosene layer.

SUMMARY.—A new method for determining the amount of kerosene deposited on citrus leaves by toxic kerosene sprays is presented. This method involves the selective chemical disintegration of the leaf cells, accompanied by a steam distillation of the stable oils present. The apparatus necessary for this method is described in detail. Typical results obtained when the method was applied to field experiments are presented. In one such experiment the coefficient of variation of this method was determined to be 0.0467. The only probable source of error is discussed.

It is shown that the major portion of the kerosene "absorbed" by the leaf probably goes into solution in the natural waxes and oils elaborated inside the leaf cells.—1-19-42.

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The Stupefaction of California Red Scale with Sublethal Dosages of Hydrocyanic Acid

HAROLD R. YUST, HOWARD D. NELSON, and R. L. BUSBEY, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

It was observed by Gray & Kirpatrick (1929) that exposure of the California red scale, *Aonidiella aurantii* (Mask), to a sublethal concentration of hydrocyanic acid prior to fumigation with a normally lethal concentration reduced the kill. The effect was called protective stupefaction and has been studied since then by other investigators both in the laboratory and in the field. This paper includes observations made in the laboratory on protective stupefaction in resistant and nonresistant strains of scales under different temperatures and with different intervals of time between the treatments with sublethal and lethal dosages, and also some observations made in the field on protective stupefaction in several of the insect's developmental stages.

The methods and apparatus used in the laboratory fumigations were the same as those described by Yust *et al.* (1942). The scales were on lemon fruits. The nonresistant scales were reared at a constant temperature of 77° F. and a relative humidity of 65 per cent, and were treated in the laboratory fumigation chamber under controlled conditions. Those fumigated at 59° F. were held at that temperature for 4 hours before and after treatment. The resistant scales were reared in a lath house at temperatures comparable to those in the field, and were treated in the fumigation chamber at night under conditions similar to those in commercial field fumigations. Fifty scales on each of a number of fruits were included in each experiment. The sublethal dosages alone in the laboratory fumigations did not produce any kill.

Field fumigations were made in the vicinity of Corona on lemon trees infested with resistant scales. Two neighboring groups of approximately 16 trees each were fumigated with a 24-cc. schedule in two exposures (throws) on each of five nights. The groups were fumigated in successive 45-minute exposures as in commercial fumigations; so the scales treated in the second throw were subjected to the sublethal dosage of gas leaking through the tents which covered the other group of trees during the first throw.

INFLUENCE OF INTERVAL BETWEEN EXPOSURES ON KILL.—Two groups of 900 nonresistant mature female scales were fumigated at 59° F. One group was exposed to a sublethal dosage of 0.026 mg. of hydrocyanic acid per liter for 10 minutes, and immediately afterward both groups were exposed to a lethal decreasing dosage ranging from 0.34 mg. per liter at the start to 0.05 mg. at the end of 40 minutes. A kill of 95.2 per cent was obtained in the group exposed to the lethal dosage alone, but only 88.7 per cent were killed in the group previously exposed to the sublethal dosage. The sublethal dosage produced marked protective stupefaction. Stupefaction was also observed in other experiments similar to this, but with a constant instead of a decreasing lethal dosage.

Two groups of 1,200 nonresistant mature female scales were also fumigated at 59° F., but the sublethal dosage given one

group, which was 0.05 mg. per liter for 10 minutes, was 1 hour prior to the simultaneous fumigation of both groups with a lethal dosage of 0.11 mg. per liter for 40 minutes. With only the lethal dosage the kill was 70.1 per cent, but with a sublethal dosage 1 hour prior to the lethal dosage the kill was 84.5 per cent. The latter kill is significantly higher than the former. This experiment was repeated under similar conditions but with a sublethal dosage of 0.025 mg. per liter; the kill with only the lethal dosage was 68.7 per cent and with the sublethal treatment prior to the lethal treatment 72.7 per cent. Since these kills were not significantly different, the higher sublethal dosage in the previous experiment may have been responsible for the higher kill in the prefumigated scales. It was concluded from these experiments that any stupefaction resulting from exposure of nonresistant mature female scales to sublethal dosages of hydrocyanic acid at 59° F. disappeared within an hour.

Lindgren (1938) observed that the kill of nonresistant scales was reduced when 1 hour elapsed between the exposures to sublethal and lethal dosages in fumigations at from 73° to 76° F. Since his results and those described above were obtained at different temperatures, further tests were made at a higher temperature. Four groups of 1,200 nonresistant mature female scales were fumigated at 77° F. to see if they remained stupefied as long as 2 hours after they were exposed to a sublethal dosage. Three of the groups were fumigated with a sublethal dosage of 0.025 mg. per liter for 10 minutes prior to the simultaneous fumigation of all four groups with a lethal concentration of 0.2 mg. per liter for 40 minutes. The results are shown in table 1.

Table 1.—Influence of the interval between exposures to sublethal and to lethal dosages on the kill of nonresistant mature female red scales at 77° F.

Treatment	Interval, Hours	Mortality, Per Cent
Lethal dosage	—	83.8±1.5
Sublethal and lethal dosage	None	79.5±2.7
	1	57.0±4.6
	2	52.4±3.5

The kill was not reduced significantly when the exposure to the stupefying charge was immediately before the regular lethal fumigation, but when an interval of 1 to 2 hours occurred between the sublethal and the lethal fumigation the kill was greatly reduced. In general, the results obtained verify those obtained at comparable temperatures by Lindgren. They also indicate that the reaction of the insect to a stupefying dosage at 59° is different from that at 77° F. The importance of studying the influence of the various factors on the kill under conditions comparable to those existing in field fumigations is thus evident.

Lindgren (1938) also reported an increased kill when 2 hours elapsed between exposures to sublethal and lethal dosages in fumigations of resistant mature female scales at 73° to 76° F. To determine if the same reaction was obtained under field conditions, an experiment was made with resistant mature female scales reared outdoors from August 11 to October 10, 1941. In order to control the sublethal dosages the experiment was made in the laboratory fumigation chamber but under conditions simulating those in the field. Five groups of 1,200 scales were included, four of which were exposed once each successively for 45 minutes to sublethal dosages ranging from 0.15 mg. per liter at the start to 0.04 mg. at the end. All the groups were then fumigated simultaneously with a dosage ranging from 2.38 mg. per liter at the start to 0.18 mg. at the end of 45 minutes. Both the sublethal and the lethal concentrations were comparable to those used in field fumigations. The results of this experiment are shown in table 2.

Table 2.—Influence of the interval between the exposures to sublethal and to lethal dosages on the kill of resistant scales reared and fumigated at outdoor temperatures (58°–65° F.).

Treatment	Interval Between Exposure, Minutes	Mortality, Per Cent: Mature females	Mortality, Per Cent: Scales in second molt
Lethal dosage only	—	99.4±0.2	94.6±0.8
Sublethal and lethal dosage	10	72.6±2.5	47.0±2.1
	65	74.9±1.7	82.8±1.2
	120	88.5±1.0	94.2±0.6
	175	96.1±0.7	

Sublethal exposures completed 10 and 65 minutes before exposure to the lethal dosage gave about the same reduction in

kill. The stupefying effect was partly lost in 120 minutes and even more in 175 minutes, but it was not completely lost.

A similar experiment was made with resistant scales in the second molt reared at outdoor temperatures from June 12 to July 12, 1941. There were four groups of 1,200 scales in the treatment, three of which were fumigated once successively in 45-minute exposures to sublethal dosages ranging from 0.13 mg. per liter at the start to 0.03 mg. at the end. All the groups were then fumigated simultaneously with a decreasing dosage ranging from 2.34 mg. per liter at the start to 0.12 mg. at the end of 45 minutes. The data are given in table 2.

An appreciable amount of the stupefaction was lost in 65 minutes, and all of it was lost in 120 minutes. Under the conditions of this experiment a period equivalent to two field fumigation exposures elapsed before the stupefying effect was completely lost in scales in the second molt.

INFLUENCE OF REPEATED SUBLETHAL DOSAGES.—Scales in the second molt reared from June 12 to July 12, 1941, at outdoor temperatures were also fumigated with two and three 45-minute exposures to sublethal dosages under the conditions outlined for the preceding experiment. Ten minutes elapsed between the final sublethal exposure and the lethal exposure. The mortality without exposure to sublethal dosage was 94.6 ± 0.8 per cent (Table 2); with one exposure to a sublethal dosage just before exposure to the lethal dosage the kill was 47.0 ± 2.1 per cent (Table 2); with two exposures, 41.1 ± 1.4 per cent; and with three exposures, 43.5 ± 1.6 per cent. The mortality was reduced about the same with one exposure to a sublethal dosage just before the lethal dosage as with three sublethal exposures. The repeated exposures to sublethal dosages therefore continued the stupefying effect without any appreciable kill.

SUBLETHAL CONCENTRATIONS AND DIFFERENT DEVELOPMENTAL STAGES.—Quayle (1922) stated that scales in the second molt were more difficult to kill than mature female scales. This finding has been verified many times by the authors in laboratory and field fumigations when there was no stupefaction. To determine whether the same reaction occurred in field fumigations when the scales were first subjected to sublethal dosages, the differences in kill between mature female scales and scales in the second molt and early gray adult stages in the first exposure, or throw, were compared with the differences in kill between the same stages in the second exposure. Scales in the early gray adult stage were included with those in the second molt, as they are about equally difficult to kill without stupefaction. The scales treated in the second throw were subjected to the sublethal dosage of gas leaking through the tent during the first throw.

In practical field fumigation the same dosages will result in concentrations that will vary between throws and between tents in the same throw; moreover, factors that influence kills will vary from one night to another. Comparisons of kills obtained in different throws therefore are not made.

Mortality counts for each throw were made by taking approximately 15 infested fruits from 4 trees and counting all the scales in the stages being compared, so that the kills could be compared under the same conditions. The data are given in table 3.

Table 3.—Relative influence of sublethal concentrations of hydrocyanic acid on mature female scales, and scales in the second molt and early gray adult stages in five field fumigations.

Night	Scales in Second Molt and Early Gray Adult Stages		Mature Females	
	Number	Mortality (per cent)	Number	Mortality (per cent)
First throw for each night				
1	633	96.1 ± 2.7	1,068	100.0
2	516	85.9 ± 3.3	452	95.8 ± 0.6
3	409	98.8 ± 0.4	455	100.0
4	1,280	96.8 ± 2.9	1,586	100.0
5	1,070	86.8 ± 3.6	1,009	98.6 ± 1.1
Average (unweighted)		92.9 ± 1.3		98.9 ± 0.3
Second throw for each night, scales subjected to drift gas				
1	760	85.1 ± 5.7	1,112	80.9 ± 3.0
2	662	80.3 ± 2.6	575	74.5 ± 7.2
3	635	99.4 ± 0.6	708	95.0 ± 1.9
4	1,452	98.3 ± 0.5	1,861	86.3 ± 2.1
5	1,050	96.1 ± 2.5	986	91.8 ± 4.1
Average (unweighted)		91.8 ± 1.4		85.7 ± 1.9

In the first exposure without stupefaction the kill of the mature female scales on five nights was consistently higher than the kill of the scales in the second molt and early gray adult stages. In the second exposure, after stupefaction had occurred, the relative susceptibility of the stages was reversed; the kill of the scales in the second molt and early gray adult

stages on five nights was consistently higher than the kill of the mature female scales. These results show that the mature female scales may be more difficult to kill in the field than scales in the second molt and early gray adult stages when the insects are first subjected to sublethal dosages, as they are likely to be in all the throws after the first. Under the conditions in these experiments the stages reacted differently to the sublethal dosages of hydrocyanic acid and the stupefaction was greater with the mature female than with scales in the second molt and early gray adult stages. It should not be concluded that the scales in these stages were not protected, for in the previous experiments in the laboratory under conditions simulating those in the field sublethal dosages stupefied scales in the second molt as well as the mature female scales.

SUMMARY.—In laboratory fumigations of nonresistant mature female scales with hydrocyanic acid at 59° F., exposure to a sublethal dosage for 10 minutes immediately before exposure to the lethal dosage produced marked protective stupefaction, but the stupefaction was lost at this temperature when 1 hour elapsed between exposure to the sublethal and the lethal dosage. At 77° F., nonresistant mature female scales were not markedly stupefied when exposed to the same sublethal dosage immediately before the lethal dosage, but were stupefied to a significant extent when 1 hour elapsed between the sublethal and the lethal dosage.

In laboratory fumigations simulating conditions in field fumigations resistant mature female scales were stupefied with a 45-minute exposure to a sublethal dosage applied immediately prior to the lethal dosage. The stupefying effect was partly lost in 2 hours but not completely lost in 3 hours. Under the same conditions scales in the second molt were stupefied with the same sublethal dosage immediately prior to the lethal dosage, and the stupefying effect was dissipated in 2 hours. The stupefactive effect of exposure for three successive 45-minute periods to a sublethal dosage was the same as that of a single 45-minute exposure.

In the first throw in field fumigation, when there was no stupefaction due to previous exposure to sublethal dosages, the scales in the second molt and early gray adult stages were more difficult to kill than mature female scales. However, when stupefaction occurred, as in the second throw, the reverse was found true.—1-6-42.

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DR. GIBSON RETIRES AS DOMINION ENTOMOLOGIST

Dr. Arthur Gibson, Dominion Entomologist of Canada since 1920 and for 42 years engaged in entomological work in Canada, retired from active service on January 15, 1942.

Dr. Gibson is a past president of the American Association of Economic Entomologists and he served in the same capacity in the Entomological Society of America.

The distinguished entomological services of Dr. Gibson are too numerous and too well known to require enumeration here. But many entomologists will best remember him for many courtesies and for his helpful cooperation. In a very real sense Dr. Gibson helped maintain the unity of American entomology and even in his period of retirement he can not fail to continue to exert his influence for good will and unity of effort.

The best wishes of the Association are extended to Dr. Gibson on this occasion along with the hope that he will continue his activities in the Association.

A Comparison of the Susceptibility of the So-Called Resistant and Nonresistant Strains of California Red Scale to Methyl Bromide

HAROLD R. YUST, and R. L. BUSBEY, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

Many investigators have observed that California red scales, *Aonidiella aurantii* (Mask.), are more difficult to kill with hydrocyanic acid gas in some localities in southern California than in others. The scales in the former localities have been termed the "resistant" strain, and those in the latter have been termed the "nonresistant" strain. The question naturally arises whether the same difference exists between the two strains in treatments with other fumigants. Quayle (1938) states that his data seem to indicate that the same difference in the susceptibility of the two strains is manifested in treatments with methyl bromide and ethylene oxide. In this study the relative susceptibility of the two strains to methyl bromide was observed.

APPARATUS AND PROCEDURE.—The apparatus used and the methods and procedure followed were the same as those used by Yust *et al.* (1942) in the laboratory tests on the California red scale with methyl bromide. Both strains of scales were reared and treated simultaneously in the laboratory on lemon fruits at a constant temperature of 77° F. After treatment the scales were held at a constant temperature of 77° F. until the mortality counts were made. Fifty scales were tested on each lemon fruit, all of which were marked prior to treatment. The number of fruits in each test varied as is indicated. In all cases the scales were exposed to constant concentrations of the gas and the exposures were for a period of 40 minutes unless otherwise stated. The scales used in all these treatments were offspring of the two strains established in the laboratory insectary.[1]

COMPARISON OF DEVELOPMENTAL STAGES.—Resistant and nonresistant strains of the California red scale in the second molt and in the gray adult and mature female stages of development were fumigated as indicated in table 1. The scales in the second molt were 20 and 21 days old, those in the gray adult stage 25 days old, and those in the mature female stage 38 days old. For comparative purposes the mortalities from hydrocyanic acid fumigation were included for each of the stages. The mortality record for each strain in each stage was based on 1,200 insects, except in the methyl bromide treatment of the mature female stage, where each mortality record was based on 800 insects.

Table 1.—A comparison of the mortalities of both strains of the California red scale in three developmental stages.

Stage of Development	Methyl Bromide			Hydrocyanic Acid		
		Mortality			Mortality	
	Concentration (mg./l.)	Resistant (Per Cent)	Nonresistant (Per Cent)	Concentration (mg./l.)	Resistant (Per Cent)	Nonresistant (Per Cent)
Second Molt	30	96.2±0.7	95.2±0.6	0.60	14.6±2.2	98.9±0.3
Early Gray Adult	80	96.1±0.9	83.0±1.9	0.59	41.1±2.7	99.6±0.2
Mature Female	55	77.0±3.6	94.4±1.4	0.48	54.9±2.5	98.6±0.4

In the methyl bromide treatments the mortalities of the two strains in the second molt were not significantly different. In the early gray adult stage there was a significantly higher kill of the scales in the

[1] A study of resistant and nonresistant strains of California red scales was commenced at the Whittier laboratory by the late F. S. Stickney in 1934. Scales from several localities were tested with hydrocyanic acid gas and it was found that the scales from Escondido were relatively easy to kill (nonresistant) and those from Corona were relatively difficult to kill (resistant). Consequently, in the spring of 1935 nonresistant scales from Escondido and resistant scales from Corona were placed in adjacent compartments in the station insectary. The scales of both strains were maintained on young lemon trees growing in pots, and have retained their original differences in susceptibility to hydrocyanic acid.

so-called resistant strain than in the so-called nonresistant strain. In the mature female stage the kill was significantly lower in the so-called resistant strain than in the so-called nonresistant strain. However, the difference between the two strains was not as great as it was in the treatments with hydrocyanic acid. In the hydrocyanic acid treatments the kill of the nonresistant scales was significantly higher than that of the resistant scales in each of the developmental stages.

Previously both mature female scales and those in the early gray adult stage had been treated with methyl bromide at only one age. Since it has been shown by Yust *et al.* (1942) that difference in age definitely influences the kill, the scales in the above two conditions were fumigated at several ages to see if the difference between the strains existed at several ages.

Scales 23, 24, 25, and 26 days old were treated simultaneously in the gray adult stage. In both strains the 23-day-old insects had just molted and were the same size as those in the second molt. The 26-day-old insects were in the late gray adult stage and had increased in size by adding marginal wax to the scale covering.

Mature female scales 44, 45, 46, and 47 days old were also treated simultaneously. Both strains were about ready to reproduce but reproduction had not commenced. Older scales were selected for this test than in the previous test because of the increased resistance of the older mature insects.

The fumigations of both stages were duplicated in two successive exposures. Three hundred scales of each age and strain were fumigated in each exposure, or the mortality of each age was based on 600 insects. The scales in the gray adult stage were fumigated with a concentration of 70 mg. per liter and the mature female scales with 65 mg. per liter. The results are presented in table 2.

In the gray adult stage a better kill of the so-called resistant strain was obtained at each age. However, the kills of the two strains of 23-day-old insects were not significantly different. The kills of the two strains of the other three ages were significantly different and the average mortality of the resistant strain (83.8 per cent) was significantly higher than the average mortality of the nonresistant strain (75.1 per cent), as indicated by the analysis of variance with angle transformations (Bliss 1938) ($F = 1055.10/45.29 = 23.30$ for 1 and 90 degrees of freedom).

Table 2.—The mortalities of both strains of the California red scale in the gray adult and mature female stages at several ages, following fumigation with methyl bromide. (Fumigation period 40 minutes; concentration 70 mg./l. for gray adult stage and 65 mg./l. for mature female scales.)

Age (Days)	Percentage Mortality of Each Strain	
	Resistant	Nonresistant
(a) Gray Adult Stage		
23	75.0	73.7
24	72.7	54.0
25	91.5	79.7
26	95.8	93.0
Average	83.8	75.1
(b) Mature Female		
44	61.7	72.7
45	56.2	73.2
46	58.8	69.2
47	62.7	69.3
Average	59.8	71.1

In the mature female stage the kill of the so-called nonresistant scales was better at each age than the kill of the so-called resistant scales. However, the kills of the two strains of 47-day-old insects were not significantly different. The difference between the kills of the two strains was significant for the other three ages and the average mortality of the nonresistant strain (71.1 per cent) was significantly higher than the average mortality of the resistant strain (59.8 per cent) as indicated by the analysis of variance ($F = 759.38/39.71 = 19.12$ for 1 and 90 degrees of freedom).

CONCENTRATION-MORTALITY TESTS.—Early gray adult scales of both strains were treated at four concentrations, namely, 60, 70, 80, and 90 mg. per liter. The four exposures were made in succession and replicated on 3 successive days. On each day 400 scales of each strain were fumigated simultaneously with each concentration, or a total of 1,200 insects of each strain were treated with each concentration. The scales were 25 days old.

The kills were corrected for natural mortality. There was 2.5 per cent natural mortality of the resistant strain and 3.5 per cent natural mortality of the nonresistant strain.

At each of the above concentrations there was a significantly better kill of the

so-called resistant scales than of the so-called nonresistant scales. The regression equation for the resistant strain was $Y=5.75+25.04(X-1.863)$ and for the nonresistant strain was $Y=5.34+24.52(X-1.876)$. In the resistant strain the standard errors of the average probit and regression coefficient were 0.06 and 1.88, respectively, and in the nonresistant were 0.07 and 1.83, respectively. The percentage kills at the lowest concentration of each strain were not used in the calculation of the above two equations as suggested by Bliss (1935) because they did not seem to fit the provisional regression lines. The median lethal concentration of methyl bromide for the nonresistant strain was 73 mg. per liter and for the resistant strain was 68 mg. per liter.

Table 3.—The mortalities of both strains of the California red scale at four concentrations. (Early gray adult stage; exposure period 40 minutes.)

CONCENTRATION OF METHYL BROMIDE (MG. PER LITER)	PERCENTAGE MORTALITY OF EACH STRAIN	
	Resistant	Nonresistant
60	15.1±1.0	11.3±2.0
70	61.9±2.5	34.5±2.6
80	96.1±0.9	83.0±1.9
90	99.7±0.2	99.0±0.3

TIME-MORTALITY TESTS.—Early gray adult scales of both strains were also treated for four different periods, namely, 120, 140, 160, and 180 minutes. The concentration was 20 mg. per liter in each exposure. The four exposures were made in succession and replicated on 6 successive days. On each day 200 scales of each strain were fumigated simultaneously, that is, a total of 1,200 insects of each strain were treated for each length of time. The scales were 25 days old.

As may be seen in table 4, there was a slightly better kill of the so-called resistant scales than of the so-called nonresistant scales at each length of exposure. Yet in no cases were the differences statiscally significant.

Table 4.—The mortalities of both strains of California red scale in exposures of four different periods. (Early gray adults; dosage 20 mg./l.)

LENGTH OF EXPOSURE (MINUTES)	PERCENTAGE MORTALITY OF EACH STRAIN	
	Resistant	Nonresistant
120	36.5±2.4	30.7±3.4
140	87.7±1.6	85.1±1.8
160	98.8±0.4	96.4±1.4
180	100.	99.9±0.08

SUMMARY.—In tests with the California red scale made at the Whittier, Calif., laboratory the so-called resistant scales in the mature female stage were also resistant to methyl bromide and the so-called nonresistant scales of the same stage were nonresistant to methyl bromide, but the difference that existed in the susceptibility between the two strains to methyl bromide was less than the difference that existed between the two strains to hydrocyanic acid. Scales of the so-called resistant strain in the early gray adult stage of development were more susceptible to methyl bromide than scales of the so-called nonresistant strain in the same stage of development in 40-minute fumigations, but not in 120- to 180-minute fumigations. There was no difference in susceptibility of the two strains of scales in the second molt to methyl bromide in the limited number of tests made.—1-6-42.

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Influence of Tartar Emetic on the Yellow Scale and Its Parasite, *Comperiella bifasciata* (How.)[1]

J. K. Holloway, Chas. F. Henderson, and Horace V. McBurnie, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

The use of toxicants for the control of a specific insect in a locality in which other insects are present on the same host but are not influenced by the toxicant could cause an abnormal increase in the other insects by affecting the parasite populations. It is possible that the use of tartar emetic for the control of the citrus thrips, *Scirtothrips citri* (Moult.), in locations in which the yellow scale, *Aonidiella citrina* (Coq.), and its parasite *Comperiella bifasciata* (How.) are existent presents a problem of this nature. Laboratory experiments have shown that a spray consisting of tartar emetic and sugar is very toxic to *Comperiella*. Therefore, if tartar emetic caused no decrease in yellow scale populations, and the parasites fed upon the deposits in the field, there might possibly be an increase in the yellow scale resulting from the use of tartar emetic. Experiments were designed to study the influence of tartar emetic on host and parasite populations. Two tests were made in 1940 and one in 1941 in the vicinity of Redlands, San Bernardino County, Calif.

Experimental Procedure.—In the two experiments conducted in 1940, 1.5 pounds of tartar emetic and 2 pounds of sugar were used per hundred gallons of spray, the application being made by the spray-gun method. This is one of the dosages recommended for control of thrips on citrus (Persing *et al.* 1940). The treated and check plots consisted of three by four trees each, the treatment and check being replicated eight times. Population counts were made on the two central trees in each of the plots.

In 1941 the recommended method of application had been changed from the ordinary spray-gun method used in 1940 to the present one of atomizing the spray and blowing it on the tree with a power blower (Persing & Boyce 1941). In the spray-duster application 20 gallons of spray containing 1.5 pounds each of tartar emetic and sugar were applied per acre. In this experiment single-tree plots were used, a check being obtained by covering the trees with fumigation tents which were removed after the spray had settled on the other trees in the grove. The application was made at night so that it was not necessary to cover the trees until dusk, any adverse conditions resulting from excessive heat within the tents being thereby kept at a minimum. The use of tents did not disturb the adult parasite populations to any great extent, since only a small fraction of the total emergence had begun.

The comparative populations in all the experiments were obtained by taking a 10-leaf sample from each tree. The living and parasitized mature scales were counted on half the total leaf area, which included a portion of the top surface and a portion of the bottom surface of each leaf. The midrib was used as the dividing line because it extends the full length of the leaf and is common to the top and bottom surfaces. Records of the scale distribution on leaves showed that a half-leaf area composed of a quarter from the top of the leaf and a quarter from the bottom diagonally opposite gave a very close approximation to half the total leaf population, with the same relative variability as the whole leaf. The use of half leaves greatly reduced the amount of microscope work with no appreciable loss in accuracy.

A small sample of 20 leaves at the rate of 4 leaves from each of 5 trees was taken at weekly intervals. This was done to obtain a record of the progressive development of host and parasite. The comparative population counts of the mature-host and immature-parasite stages were made when approximately 50 per cent of the parasites had reached the pupal stage. Making the counts at this time greatly facilitated the dissecting work because the stages which had not yet pupated were well enough advanced to be readily seen.

Results.—The results of the experiments of 1940 with tartar emetic are summarized in table 1.

In the Curtis grove the test plots were located in a planting of Mediterranean Sweet and St. Michael orange trees, while in the Cram grove the planting was a variety of navel orange. Both groves were

[1] These investigations were conducted in cooperation with the Citrus Experiment Station, of the University of California.

treated on May 1, the Curtis grove receiving a second application on June 11.

There was no significant difference in the number of living or parasitized scales between the treated and untreated plots within the experimental groves. The reduction in both living and parasitized scale populations in the Curtis grove from June to July was associated with a high rate of mortality of mature senile scales that had not been replaced by mature scales originating from the spring generation. This condition was, however, common to both treatment and check plots.

On June 17, 6 days after the second application of tartar emetic in the Curtis grove, a count of adult parasites was made by recording the number of adults observed on 50 leaves for each count tree. At this time there were 34 adult parasites in the untreated plots and 35 in the treated. This would indicate that no marked attraction or repulsion was associated with the trees treated with tartar emetic.

In 1941 the experimental plots were located in a planting of navel oranges in the East Highlands Orange Company grove. The results of counts taken in these plots are summarized in table 2.

There was no significant difference in the numbers of living or parasitized scales that could be associated with the use of tartar emetic.

Table 1.—Comparative numbers of mature living and parasitized yellow scales on trees treated with tartar emetic and on check trees in two experimental groves, 1940.

Collection Date	Curtis Grove				Cram Grove			
	Treated Trees		Check Trees		Treated Trees		Check Trees	
	Living Scales	Parasitized Scales	Living Scales	Parasitized Scales	Living Scales	Parasitized Scales	Living Scales	Parasitized Scales
	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
June	366	188	350	150	21	32	10	14
July	66	27	87	34	16	6	11	6
August	131	28	117	18	13	4	26	4
Total	563	243	554	202	50	42	47	24
Grand Total	806		756		92		71	

Table 2.—Comparative numbers of mature living and parasitized scales on tartar emetic-treated and untreated check trees, 1941.

Date	Treated Trees		Untreated Trees	
	Living Scales	Parasitized Scales	Living Scales	Parasitized Scales
	Number	*Number*	*Number*	*Number*
April[1]	277	59	253	39
June	297	53	314	87
August	176	26	133	15

[1] Before treatment.

SUMMARY AND CONCLUSIONS.—Three field experiments were conducted to determine the effect of tartar emetic, as applied for control of the citrus thrips, upon populations of the yellow scale, *Aonidiella citrina* (Coq.), and its parasite *Comperiella bifasciata* (How.), occurring on the same trees. In laboratory tests tartar emetic was found to be toxic to adults of the parasite.

Field tests demonstrated that this spray material did not influence yellow scale populations, nor were there any significant differences in parasitization by *Comperiella* in the treated and check plots. It may therefore be concluded that, as a source of food, the deposits are not attractive to the parasites under field conditions.—1-6-42.

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Population Increase of Citrus Red Mite Associated with the Use of Sprays Containing Inert Granular Residues

J. K. Holloway, Chas. F. Henderson, and Horace V. McBurnie, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*[1]

High populations of the citrus red mite, *Paratetranychus Citri* McG., have been observed by some workers in groves or portions of groves in which there has been a heavy accumulation of road and orchard dust on the foliage. Among the many factors which might cause an abnormal increase in red mite numbers is the possible hindrance to the activity of natural enemies by the dust. If the population increase is associated with inert deposits on the leaves, the use of sprays containing quantities of inert material in excess of the inherent grove dust should cause an increase in red mite populations.

Procedure.—Experiments were designed to study red mite populations associated with the use of sprays containing inert granular residues. In 1940 two sprays were compared, one of which was a fungicide and the other a nonfungicide. These sprays were applied in a lemon grove at Oxnard, Calif., and in a Valencia orange grove at Santa Ana, Calif. In 1941 the same two sprays were used, and in addition two chemical-deficiency sprays were included in the experiment conducted at Santa Ana.

The design used in all the experiments was that of randomized blocks, which were replicated 10 times in each grove. The blocks were separated from one another by at least one row of untreated trees. Within the blocks single-tree plots were used in order that there might be a high proportion of untreated trees and that thus the biological control of the grove might be disturbed as little as possible. Population estimates were made by counting the red mites and predators on 15 leaf samples taken at random from each tree.

Results, Oxnard, 1940.—In the winter preceding the present experiment this grove had received an oil-emulsion treatment. The experimental sprays were applied on June 5, at which time there was only a trace of red mite adults and eggs. The fungicidal spray consisted of 12 pounds of zinc, 1 pound of copper sulfate, 6 pounds of lime, and 4 ounces of spreader per 100 gallons of water. The nonfungicidal spray consisted of 3 pounds of aluminum sulfate and 3 pounds of lime per 100 gallons. Citrus red mite counts were taken on September 3 and December 3 (Table 1).

Table 1.—Number of citrus red mites per lemon leaf in treated and untreated plots, Oxnard, 1940.

Treatment	Mean Number of Mites per Leaf	
	Sept. 3	Dec. 3
Fungicide	4.11	37.95
Nonfungicide	1.15	16.40
Unsprayed check	0.93	12.75
Mean	2.06	22.37

Although the red mite population on September 3 was lower for all treatments, the influence of the fungicidal spray could be detected. On December 3 a significantly higher red mite population was associated with the fungicidal treatment. In this experiment all predators, with the exception of the predaceous mite *Seiulus* sp., were practically absent in the treated and untreated plots. In the check plots the population of *Seiulus* averaged 0.23 per leaf as compared with 0.02 in the plots receiving the nonfungicidal treatment and none in those receiving the fungicidal treatment. It is unlikely that the red mite increase in the fungicidal plots was greatly influenced by the absence of the predaceous mite, since there was no correlation between red mite density and the scarcity or abundance of the predaceous mite in the check plots. The possibility that the increase resulted from an inhibiting action of the spray on a beneficial fungus is also doubtful, since there was no evidence of a fungus disease in the plots sprayed with a nonfungicide or in the check plots.

Santa Ana, 1940.—During the fall preceding this experiment the grove had received a hydrocyanic acid gas fumigation. The experimental sprays were applied on

[1] In cooperation with the Citrus Experiment Station of the University of California, at Riverside.

June 13, at which time red mites and eggs were noticeable but not abundant. The proportions of the fungicidal spray were the same as in the Oxnard experiment. The nonfungicidal spray consisted of 6 pounds of aluminum sulfate and 6 pounds of hydrated lime per 100 gallons of water. On August 12 and November 28 citrus red mite population counts were taken (Table 2).

On August 12 the population associated with the fungicidal spray was significantly higher than that associated with the nonfungicidal treatment and check. The only natural enemy observed to occur in a measurable quantity was the predaceous mite *Seiulus*. Although the fungicidal spray did not totally exclude the predaceous mite in this experiment, the average population per leaf was much lower than in the nonfungicidal treatment and check. In the check plot there was no correlation between citrus red mite and *Seiulus* densities, and there was no evidence of the presence of a fungus disease.

Table 2.—Number of citrus red mites per lemon leaf in treated and untreated plots, Santa Ana, 1940.

	Mean Number of Mites per Leaf	
Treatment	Aug. 12	Nov. 28
Fungicide	24.85	3.49
Nonfungicide	14.75	2.48
Unsprayed check	9.63	3.41
Mean	16.41	3.13

The decreased red mite population found to exist on November 28 is of interest because of the disproportionate reduction that had occurred. This type of reduction would indicate the presence of a factor which acted with greater efficiency in the higher red mite population densities. It is improbable that a fungus disease was a factor causing reduction, since the greatest decrease occurred in the fungicidal treatment, where the effectiveness of a fungus would have been inhibited. *Seiulus* could not have been responsible, since the lowest average population of this predaceous mite occurred in plots receiving this treatment.

On September 17 a population count was made by dividing each sampled tree into two zones, the leaves of which were classified as old and new. The old leaves were on the tree at the time that the spray was applied, while the new leaves had appeared since the spray application. This division was easily made in the treated plots because both treatments left a visible deposit on the leaves. The zones were not so readily separated in the check plots. A comparison of the growth areas in the treated plots, however, indicated that a sample of new leaves taken from green wood, and of old leaves from gray wood, constituted a reasonably accurate division. A sample of 15 leaves was taken from each zone, or a total of 30 leaves from each sampled tree. The mean populations per leaf are summarized in table 3.

Table 3.—Number of citrus red mites per orange leaf on old and new foliage in treated and untreated plots, Santa Ana, September 17, 1940.

	Mean Number of Mites per Leaf			
Age of Foliage	Nonfungicide Treatment	Fungicide Treatment	Unsprayed Check	Mean
Old	2.91	4.80	1.65	3.12
New	4.32	13.33	2.99	6.88
Mean	3.61	9.06	2.32	—

The samples from which the mean populations shown in table 3 were determined were more or less systematic as compared with those used to obtain the means in table 2, in which the leaves were taken at random and various numbers from both zones were included.

The least difference between the mean number of red mites per leaf in the various treatments was found on the old leaves, and the greatest difference was on the new leaves. The treatment which underwent the greatest reduction had the highest mean number of citrus mites per leaf on the new leaves. Therefore, since the denser populations were on the new leaves while the reduction was still in progress, the factor causing the disproportionate reduction must have been associated with the number of red mites on the new foliage. There are indications that the leaves were rendered less suitable to the red mite because of the increased amount of feeding injury associated with the denser populations.

SANTA ANA, 1941.—The two treatments, as applied in 1940, did not have

equal amounts of inert residue. The nonfungicidal treatment had a total of 6 pounds in one experiment and 12 in the other, while the fungicidal treatment had a total of 19 pounds in both experiments. There was an increase associated with the nonfungicidal residue spray, but it was not significantly greater than that in the check. In 1941 the same proportions were used in the fungicidal spray, but the nonfungicidal spray had 9 pounds of aluminum sulfate and 9 pounds of hydrated lime per 100 gallons of water, or a total of 18 pounds of residue material. In addition to these applications two chemical-deficiency sprays were included. The materials and quantities used in these deficiency treatments per 100 gallons of water were as follows: Zinc sulfate 5 pounds and soda ash 2.5 pounds; manganese sulfate 5 pounds and soda ash 2.5 pounds. The sprays were applied on June 11, at which time red mites and eggs were scarce, the grove having been sprayed with oil emulsion in February.

In population counts made on September 2 the average numbers of red mites per leaf were 9.84 in the fungicidal treatment, 4.11 in the nonfungicidal treatment, 3.79 in the check, 9.15 in the zinc, and 3.30 in the manganese. The populations in the fungicidal treatment and those in the deficiency spray containing zinc did not differ from each other, and both were significantly higher than in the other treatments and check. Within the range of the quantities of the materials used the red mite increase was not influenced so greatly by the quantity as by some other characteristics of the spray. The two sprays containing zinc resulted in equal populations of the citrus red mite, although they contained a difference of 11.5 pounds of total inert residue materials. The zinc and manganese treatments had equal residue contents, but the zinc resulted in the highest mite population. The deposits on the leaves in the two treatments containing zinc appeared to be more granular than the others, and the fine webbing made by the mite adhered more readily to the zinc deposits. The possibility of a chemical stimulus which might increase longevity or egg production of the red mite was tested by laboratory experiments. Red mites were placed on leaves which had been sprayed with the same materials and proportions as were used in the field tests. There was no increase in longevity or egg production resulting from the red mite being in contact with the spray residues.

CONCLUSIONS.—The use of sprays containing zinc caused a significant increase in citrus red mite populations. This increase was not attributed to the influences on biological control factors or to a direct chemical or physical stimulus on the longevity or egg production of the red mite.

SUMMARY.—The use of sprays containing copper, zinc, manganese, lime, and soda ash were tested to determine the influence of the inert deposits on citrus red mite populations.

Populations increased following the use of a fungicidal spray containing zinc sulfate, copper sulfate, and hydrated lime, and after the use of a deficiency spray containing zinc sulfate and soda ash.

A predatory mite, *Seiulus* sp., was the only natural enemy in sufficient numbers to be recorded. The populations of this predator were the lowest in the two treatments resulting in the greatest red mite increase. The scarcity of the predator was not considered the dominant factor associated with the red mite increase, since there was no correlation between red mite and predaceous mite densities in the unsprayed check plot.

The possibility of the fungicidal spray inhibiting fungus control of the red mite is remote, as there was no evidence of a fungus being present in the check plots.

Three months after the red mite populations had reached a peak in one experiment there was a general reduction in which no difference occurred in the resulting populations between the treated and untreated plots. The disproportionate reduction could not be attributed to predators. There were indications of a reaction between the red mite and the citrus tree, which was most severe in the heaviest infestations.

Within the range of the quantities of the materials used, namely, 6 to 19 pounds of residue per 100 gallons of water, the red mite increase was associated with some physical or chemical property of the spray rather than the quantity of inert material used.

No chemical or physical influences of the sprays on longevity or egg production of the citrus red mite were observed in a laboratory experiment.—1-6-42.

The Effect of Magnesium Deficiency on Infestations of Purple Scale on Citrus

W. L. Thompson, *Citrus Experiment Station, Lake Alfred, Florida*

A magnesium deficiency in the soil of a high percentage of citrus groves in Florida previous to about 1936 was one of the main factors which made the problem of purple scale control a fairly simple one. This deficiency causes a certain type of yellowing of leaves commonly referred to in Florida as "bronzing." Briefly, the symptoms on citrus foliage as described by Camp & Fudge (1939) are, "During the summer, when a rapid increase in fruit size occurs, the symptoms appear on leaves close to the developing fruit as disconnected yellow areas lying along either side of the midrib. These areas gradually become larger and finally coalesce to form a large area of yellow tissue surrounding a triangular area of green tissue at the base of the leaf. At this stage the tip as well as the base of the leaf may be green. The yellow area may gradually enlarge until the entire leaf becomes yellow or bronze in color. By October or November, when the fruit is about mature, leaves in the vicinity of the fruit, and particularly those close to fruit clusters, will present all variations of the above stages of yellowing while leaves on the portion of the tree not bearing a crop will be normally green in color." When it became evident that a deficiency of magnesium was the cause of bronzing, that element in various forms was added to the fertilizers used with the result that a more vigorous tree is now being grown with a low percentage of bronzing leaves. Purple scale infestations have increased in severity since 1937 and the results of recent research indicate rather conclusively that where magnesium was deficient in citrus, purple scale infestations were much lighter than where no such deficiency existed. The data for this paper have been obtained from three different fertilizer experiments in the groves at the Citrus Experiment Station in which the writer has collaborated in studying the effects of various cultural practices on insect development.

Methods of Recording.—Scale populations were recorded by collecting 100 leaves at random from the outside canopy of each tree in an area 5 to 6 feet from the ground. The leaves were thoroughly mixed on a table and put back into a paper bag from which they were drawn out at random in lots of 20 leaves. Each lot of 20 leaves was examined and the number of living scales recorded. A sufficient number of lots were examined until a constant average of living scales per leaf was reached. One quarter of each leaf was examined for scales, the position of each quarter being the same in all leaves. When there was a division to be made between green and bronzed leaves, 200 leaves were collected per tree, the samples were divided into green and bronzed leaves in the laboratory and scale counts were then made from each sample.

Direct Factors Influencing Scale Development.—One of the direct factors which retards scale infestations on magnesium-deficient trees is the preponderance of bronzed leaves. From repeated examinations it has been found that bronzed leaves have had consistently fewer scales on them than green leaves of the same age, and as the severity of bronzing increased the scale population decreased (Thompson 1939, 1941). These differences were evident on three different varieties of grapefruit in a fertilizer experiment where, in two sets of duplicate plots, all fertilizer and spray treatments were identical except that in one set of plots a limited amount of magnesium had been applied which had partially corrected the severe magnesium deficiency which still existed in the other set of plots. The fertilizer experiment was started in January, 1937, and the scale counts recorded in table 1 were made in December, 1940. Without exception there was a lower average number of living scales per leaf on bronzed leaves than on green leaves regardless of whether the leaves were from trees showing a severe deficiency or from trees with a mild form of deficiency. For the past four years the general infestation has been lower in four plots where magnesium was deficient than in eight other plots where the deficiency had been corrected in varying degrees.

In another fertilizer experiment, where

a magnesium deficiency existed the scale population was definitely lower than where the deficiency had been corrected in varying degrees. The experiment was started in 1937 and examinations for scale populations was started in the fall of 1938. All plots received the same amount of nitrogen, phosphorus and potassium and any other nutrients and sprays that were needed, the only variation being in the plots receiving magnesium sulfate were sprayed only once, which is the reason for the general higher infestation in these plots compared to plots receiving dolomite (Fig. 1). In both series of plots where there was only a slight deficiency of magnesium, indicated by a low percentage of bronzed leaves, the scale population was the highest, but as the extent of magnesium deficiency increased the scale population

Table 1.—Percentage of green and bronzed leaves on three varieties of grapefruit trees with the respective scale populations.

	Plot Nos.	Type Grapefruit	Condition of Leaves Figures Expressed in Per Cent				Average Number Living Scale per Leaf			
			Green	Lightly Bronzed	Medium Bronzed	Severely Bronzed	Green	Lightly Bronzed	Medium Bronzed	Severely Bronzed
Magnesium Deficient	2	Seedless	26	17	38	19	4.40	3.24	1.92	1.28
		Med. Seedy	12	18	43	27	1.80	.88	.60	.04
		Very Seedy	7	14	51	28	3.10	2.00	.92	.24
	11	Seedless	13	19	54	14	6.08	3.48	1.44	.88
		Med. Seedy	15	16	57	12	1.40	1.24	.28	.00
		Very Seedy	19	15	52	14	1.52	1.20	.48	.12
		Average	15.3	16.5	49.1	19	3.05	2.00	.94	.42
Magnesium Supplied	3	Seedless	80	9	8	3	5.84	3.00	2.68	1.84
		Med. Seedy	63	14	14	9	1.64	1.12	.80	.34
		Very Seedy	44	13	28	15	3.32	2.44	2.88	1.76
	10	Seedless	67	12	16	5	7.20	4.88	3.32	2.34
		Med. Seedy	52	13	23	12	3.48	1.44	.80	.60
		Very Seedy	44	13	30	13	6.64	2.44	1.24	.84
		Average	58.3	12.3	19.9	9.5	4.68	2.55	1.95	1.28

amount of magnesium applied to the individual sub-plots. No nutritional sprays have ever been applied on these trees.

Two series of fertilizer plots in this experiment are considered in this discussion. One series of plots received magnesium in the form of magnesium sulfate at the rate of 50, 100, 200, and 400 pounds per acre and the other series of plots received magnesium in the form of dolomitic limestone which contained approximately 20 per cent magnesium oxide. Dolomite was applied at the rate of 200, 400, 800, and 1600 pounds per acre. In 1938 all of the plots were sprayed twice with an oil emulsion so the scale population was reduced to a minimum but no further oil sprays were applied until February, 1940, which made it possible to study the increase of scales in the several plots without interference from the effects of an oil spray on scale mortality. In 1941, the plots that received dolomitic limestone received two oil applications but, through an oversight, the decreased. Since 1938, when the first examinations were made, the average number of living scales per leaf has been lower where the magnesium deficiency exists than where it has been partially or wholly corrected. The practice of separating the bronzed and the green leaves in each plot and making separate scale counts was not started until 1940 so that these figures are not available.

To discuss further the influence of deficiencies on purple scale development, results are presented from population counts made from a third fertilizer experiment which has been conducted since 1938. These results illustrate the fact that where a magnesium deficiency existed the scale infestations were lower, even though fungicidal and nutritional sprays of copper, zinc and manganese had been applied, than on adjacent trees where the deficiency had been corrected. In former publications by Camp *et al.* (1937), Osburn & Spencer (1938), and Thompson (1938,

1939), the influence of residue sprays has been discussed. It has been found rather consistently in Florida that scale infestations are heavier following sprays that deposit a heavy residue having no insecticidal properties than where no such sprays had been applied. For a time it was thought that the fungicidal and nutritional sprays were wholly responsible for the general scale increases but upon further investigation it was found that the correction of magnesium deficiency was more of a factor influencing scale increases than the residue sprays. In this experiment there were three original plots and these were divided into halves so that the north half received magnesium derived from magnesium sulfate and dolomitic limestone and the south half received no magnesium sulfate or limestone. Other than this the fertilizer treatments were the same. Both the north and south plots were divided into four plots in the following order: Zinc-copper and manganese spray, zinc-copper spray, manganese spray, and no spray. The zinc, copper and manganese were in the sulfate form and were neutralized with hydrated lime. One change was made in the 1941 nutritional spray—the plots that had formerly been sprayed with manganese were sprayed with a combination of manganese and zinc. All plots received annual for rust mite and scale control (Fig. 2).

Trees deficient in magnesium consistently tend to have less scale than trees supplied with adequate magnesium as long as other conditions are equal. One, two and three element sprays were tried on trees deficient in magnesium and on similar trees to which magnesium had been supplied, and while the three element spray of copper, zinc and manganese produced a scale buildup in magnesium-deficient trees there was a much greater increase in scale in the trees supplied with magnesium. The copper-zinc spray showed much less buildup but the same difference between magnesium-deficient and non-deficient trees was maintained although at a lower level, and when only one element was used in the spray there was still a lower level of infestation but with the same relative difference between magnesium-deficient and non-deficient trees. If the level of scale infestation was due to the spray residue then it would seem that the scale infestation would be relatively equal on trees sprayed with the same spray regardless of the supply of magnesium. As a matter of fact the largest fluctuation in scale population was correlated with the vigor of the trees rather than the spray residue, and the vigor of the trees was correlated in turn with the supply of magnesium under the conditions of this experiment. It would seem from these and other experiments that the residue from these sprays is of importance but that tree condition is still more important as a factor in scale buildup. As a matter of fact the trees in this experiment were in some degree deficient in copper, zinc and manganese and the sprays of these elements resulted also in an increase in vigor, the greatest vigor being evident where the three elements were used together so that even the apparent effect of residue may have to be discounted.

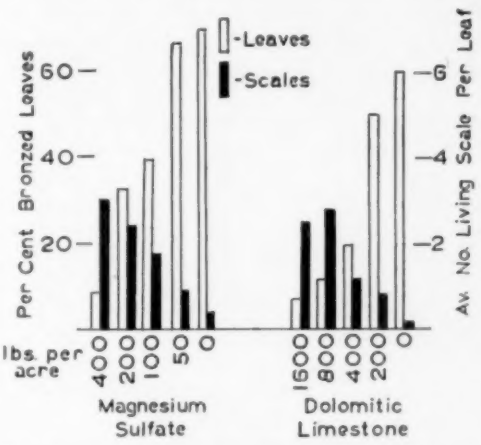

FIG. 1.—Decrease of purple scale population on magnesium-deficient trees.

Further evidence on the importance of vigor as a factor in scale buildup was obtained in another fertilizer experiment which has been conducted for 5 years and in which the yearly average of scale population has been 60 per cent lower in plots where magnesium was deficient than in plots where it was adequately supplied. All the plots received an annual spray of zinc, copper and manganese. In general over the state in sections where the soil was formerly too deficient in magnesium for proper growth of citrus, purple scale infestations have increased in number and severity since this condition has been corrected. As a matter of fact, there has been a steady increase in scale trouble through-

out those areas in which magnesium deficiency has been extensively corrected during the last few years, while in those areas where magnesium deficiency has never been acute there have been constant scale infestations of commercial importance and they are no worse today, in the main, than formerly.

keeping an infestation at a minimum. The leaves of magnesium-deficient trees drop prematurely and this is also a factor in retarding scale infestations since scales on infested leaves that drop are eliminated.

CONCLUSIONS.—Magnesium deficiency in citrus causes a chlorotic condition of the leaves known in Florida as "bronzing."

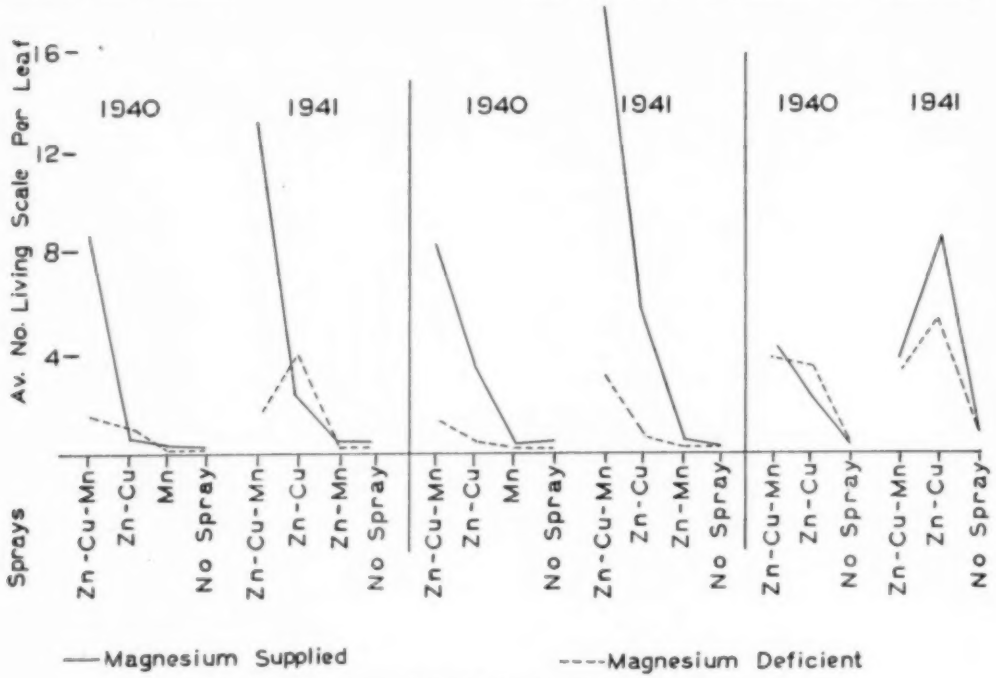

FIG. 2.—Purple scale populations following various nutritional practices.

INDIRECT FACTORS INFLUENCING SCALE DEVELOPMENT.—In all of the fertilizer experiments where direct comparisons could be made, the trees deficient in magnesium were not so well foliated as trees with sufficient magnesium. Trees of open type are not so favorable for scale development as those which are well foliated and cause a well shaded condition (Thompson 1938). The sparsely foliated trees can be more thoroughly covered with a scalecide which is an important factor in keeping an infestation at a minimum. The leaves of magnesium-deficient trees drop prematurely and this is also a factor in retarding scale infestations since scales on infested leaves that drop are eliminated.

CONCLUSIONS.—Magnesium deficiency in citrus causes a chlorotic condition of the leaves known in Florida as "bronzing." Purple scale populations on bronzed leaves were significantly lower than on green leaves of the same age. Collectively, trees with a high percentage of bronzed leaves were not so heavily infested as adjacent trees with a high percentage of green leaves where the magnesium deficiency had been corrected. Indirect factors influencing lighter infestations on magnesium-deficient trees are sparsely foliated trees, and the abnormal dropping of leaves.—1-6-42.

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Sulfur Dust as a Supplement to Cyanide Fumigation for Control of Black Scale and Its Effect on Citrus Red Mite[1]

E. A. McGregor, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

In connection with experiments for the control of the citrus thrips in central California it was observed (McGregor 1929) that applications of sulfur dust resulted in marked reductions of the populations of the citricola scale, *Coccus pseudomagnolirium* (Kuw.). Under favorable conditions this reduction often amounted to commercial control.

In 1930 the author also observed, in the course of his work in southern California (McGregor 1931), that applications of sulfur during the hatching period of the black scale, *Saissetia oleae* (Bern.), materially reduced the numbers of this insect, which is difficult to kill with cyanide in localities in southern California.

Observations and experiments carried on since that date have confirmed earlier results. In this paper experiments are reported that deal with the value of sulfur dust as a supplement to cyanide fumigation for the control of the black scale, carried on in two orchards in southern California in 1937–38 and 1938–40. In the course of these experiments records were also obtained on the effect of sulfur dusting on the citrus red mite, *Paratetranychus citri* McG.

Experiments of 1937–38.—In 1937 experiments were started in the Berkenstock Valencia orange orchard at Placentia, Calif., which was heavily infested with a strain of black scale known from experience to be difficult to control with hydrogen cyanide. A little more than half the experimental area, containing 490 trees, was dusted either two or four times, the applications being made by commercial pest-control operators. The dust used contained 98 per cent of sulfur, and 95 per cent by weight passed a 325-mesh screen.

Since sulfur is most effective against scale insects when they are hatching, the first dusting was applied at the time of the earliest observance of hatching, on May 12, 1937. An interval of from 25 to 30 days elapsed between dustings, on the assumption that the sulfur's toxicity was about spent after 3 or 4 weeks' exposure on the trees.

On August 16, 1937, some of the dusted and some of the undusted trees were fumigated with hydrogen cyanide with an 18-cc. dosage schedule (Table 1).

Three population counts were made. On June 3, 1937, counts of living mature scales were taken from four units (or twigs) from each of the north, west, south, and east quadrants of each of six trees centrally located in each plot. In all, 96 units were used in each plot.

On August 13, 1937, counts were made of live young scales in all plots. In making these counts 120 leaves, five from each of the four quadrants of each of the six record trees in each plot, were examined. At the time of these counts hatching was almost completed, and the sulfur deposits, with the exception of that from the last application, had exerted nearly their full effectiveness against the young scales. On April 27, 1938, counts of live, mature scales were again made in three of the plots. In making these counts, 20 units (twigs) were examined on each of the six test trees, five each on the north, west, south, and east quadrants of each tree, making 120 units per plot.

Summaries of the treatments applied, and the results of the counts, will be found in table 1.

The data were subjected to analyses of variance, which showed that at the outset there were no significant differences among the infestations in the plots, except for plot III, which was obviously out of line.

On August 13, after all the sulfur applications had been made and had had most of their effect, the scale population in the undusted plots I and V was very significantly greater than that in dusted plots II and IV. (Plot III was omitted from the analysis because of its low initial population.) These results indicate that the two applications of sulfur dust contributed materially to the mortality of the young

[1] These studies were made in cooperation with A. F. Swain and R. P. Buckner of the E. I. du Pont de Nemours Company, who supervised the fumigation program and permitted access to their data. The author is indebted to C. F. Henderson of the Division of Foreign Parasite Introduction for permitting the use of data on the citrus red mite.

black scales between May 12 and August 13, 1937.

The fumigation of August 16 reduced the population to such a low point that significant differences between dusted and undusted plots could not be shown. However, Messrs. Swain and Buckner, using a larger number of sample trees, found significantly lower populations in dusted plots II and IV than in undusted plot I.

EFFECT OF SULFUR ON CITRUS RED MITE.—At the time of the initial dusting (May 12, 1937) the Berkenstock orchard had a general, heavy infestation of the citrus red mite. Counts made on May 13 and 15 indicated that the percentages of mites dead in the dusted area were 96.5 and 98.8, respectively, on those dates. Considerable mite injury occurred on the trees in the undusted area, but this was not the case in the dusted plots.

In connection with the May, June, July, and August dustings in the Berkenstock orchard, no sulfur damage to the fruit or foliage was detected.

EXPERIMENTS OF 1938–1940.—Arrangements were made in 1938 to repeat the experiment discussed above. For this purpose a 5-acre Valencia orange orchard in North Whittier Heights was selected in which the black scale had a history of being very difficult to control with cyanide. This is referred to as the West orchard. Two-fifths of the orchard (Plot B) was dusted on May 23 and again on June 20; the remainder of the orchard (Plot A) was undusted. The dust used contained 98 per cent of sulfur, and 95 per cent by weight passed a 325-mesh screen. The following year (1939) the plots were reversed, plot A being dusted and B undusted. In 1940 the control programs were again reversed in plots A and B. In addition, one-third the area of plot A was converted into a third plot, C, to receive the double treatment in order that the effectiveness of sulfur plus fumigation for 2 successive years might be measured.

The entire orchard was fumigated with cyanide each summer from 6 to 10 weeks after the second dusting. The dates of the fumigations and the dosage schedules were as follows: 1938, August 8, 18 cc.; 1939, August 7–9, 18 cc.; 1940, August 15, 16 cc. These fumigations materially reduced the scale population of the generation present but made little change in the general relation between the infestations in the different plots.

Scale-population counts were taken each year in May, before the dust applications were made, and again in August, before the orchard was fumigated. The August counts were of the generation following that included in the counts made in May.

The spring counts were made of adult female scales on twigs. In 1938, 96 twigs were examined in each plot. Two twigs or units were taken from each of the north, west, south, and east quadrants of each of 12 trees of both plots. The experimental trees were situated centrally in each plot. In 1939 the sample consisted of 120 twigs,

Table 1.—Summary of experiments of 1937–38 with the use of sulfur against the black scale, Berkenstock orchard, Placentia, Calif.

Plot	Number of Trees	Number of Dust Applications	Fumigation Treatment, Aug. 16, 1937	Living Scales		
				Mature, per unit June 3, 1937	Young, per leaf Aug. 13, 1937	Mature, per Unit Apr. 27, 1938
I	70	None	Applied	5.4	65.7	.19
II	116	2[1]	Applied	4.4	19.2	.07
III	104	4[2]	—[3]	2.8	6.5	—[4]
IV	64	2[1]	Applied	5.6	16.2	.10
V	136	None	Omitted	5.3	82.4	—[4]

[1] May 12, 0.70 lb. per tree.
June 6, 0.46 lb. per tree.
[2] May 12, 0.70 lb. per tree.
June 6, 0.46 lb. per tree.
July 6, 0.77 lb. per tree.
Aug. 5, 0.59 lb. per tree.
[3] Applied to half the plot.
[4] Counts omitted, since comparisons with plots I, II, and IV were not justified.

8 twigs or units from each of 15 trees in each treatment. In 1940 the count for each plot consisted of 192 units, 16 from each of 12 trees in each treatment.

The August counts were made of living young scales on leaves. In 1938 and 1940 the sample consisted of 240 leaves, 20 from each of 12 trees in each plot. In 1939 the counts were made on 180 leaves, 20 from each of 9 trees in each plot.

Summaries of the treatments (except the fumigations, which were applied to the entire orchard each August) and the scale-population counts are given in table 2.

Table 2.—Summary of experiments of 1938–40 with the use of sulfur against the black scale, West orchard, Whittier, Calif.

	Experiments of 1938			Experiments of 1939			Experiments of 1940		
Plot	Live mature scales per unit, May 21	Dust applications	Live young scales per leaf, Aug. 8	Live mature scales per unit, May 11	Dust applications	Live young scales per leaf, Aug. 7	Live mature scales per unit, May 1	Dust applications	Live you g scales per leaf, Aug. 12
A	2.7	None	38.5	11.2	2[2]	17.2	0.5	None	12.6
B	1.8	2[2]	5.0	0.4	None	26.5	1.6	2[4]	1.8
C[1]	2.7	None	38.5	11.2	2[3]	17.2	0.5	2[4]	0.6

[1] Part of plot A in 1938 and 1939.
[2] May 23, 0.78 lb. per tree.
June 20, 0.80 lb. per tree.
[3] June 3, 0.93 lb. per tree.
June 24, 0.93 lb. per tree.
[4] May 15, 0.93 lb. per tree.
June 5, 0.93 lb. per tree.

As in the earlier experiments, the data were subjected to analyses of variance. At the start of the experiments no significant difference was found between the populations of the two plots. In all subsequent counts shown in table 2, with one exception, discussed later, there were highly significant differences between the populations in plots receiving different treatments.

The results of these experiments show clearly the value of sulfur dusting in the control of the black scale. With fumigation alone, plot A showed an increase from 2.7 to 11.2 scales per unit, from May 21, 1938, to May 11, 1939. On the other hand, with two sulfur dustings and a fumigation, plot B showed a decrease of from 1.8 to 0.4 scales per unit during the same period.

Although no significant difference between the populations in the two plots existed in August 1939, following the reversal of the plot treatments, the figures reflect favorably the effectiveness of the sulfur-dusting program, since the population of plot A prior to dusting that season was about 26 times that of plot B.

The highly significant difference in the population levels of plots A and B on May 1, 1940, favored plot A, which received two sulfur dustings and a fumigation in 1939 and which, prior to the treatments of 1939, had averaged 26 times as many scales per unit as plot B, which was fumigated but not dusted in 1939.

The trends just outlined were continued during 1940. Although plot B had more than three times as many scales as plot A at the beginning of the year, the population in the former plot, following two dust applications, was significantly lower than that in plot A, undusted. The population in plot C was significantly lower than that in plot B on August 12, 1940, which indicates the accumulative benefit of two successive years of sulfur dusting.

Counts were also made on May 1, 1941, but the figures will not be given, since the infestation in all plots had dropped to 2 scales per 100 twigs or less. With such low infestation it is obvious that no comparisons of treatments can be made for that date. Such decimations as those which took place between August 12, 1940, and May 1, 1941, were previously rarely encountered. It is generally known that the population level of the black scale became very low in many localities in southern California during the fall and winter of 1940-41; by many this has been attributed to a parasite.

Effect of Sulfur on Citrus Red Mite.—In connection with the studies in the West orchard, Mr. C. F. Henderson of

the Division of Foreign Parasite Introduction conducted counts at intervals of the citrus mite populations in both plots during 1939. His data are summarized in table 3, which follows.

Table 3.—Effect of sulfur dusting on citrus red mite infestation, West orchard, Whittier, Calif., 1939.

Date (1939)	Plot A[1] Average number of mites and eggs per leaf	Plot B[2] Average number of mites and eggs per leaf
May 15	1.67	1.69
June 1	3.76	9.49
	Dusted June 3	Not dusted 1939
June 12	1.27	6.71
June 20	.33	11.64
	Dusted June 24	
July 19	.08	17.31
Aug. 19	.24	14.00
Sept. 19	.13	.64
Dec. 7	.00	.00

[1] Not dusted in 1938.
[2] Dusted in 1938.

The data indicate that the dustings of June 3 and 24 materially reduced the mite population. The marked decrease in population in plot B following August 19 was due to the occurrence of temperatures above 100° F., which caused heavy mortality of the citrus mite.

In connection with the May and June dustings in the West orchard in 1938, 1939, and 1940, no sulfur damage to the fruit or foliage was detected.

SUMMARY.—The studies of 1937–1938 at Placentia, Calif., and those of 1938–40 at North Whittier Heights demonstrated that two applications of 325-mesh sulfur dust, applied during the period of hatching, significantly reduced the populations of the black scale. When the sulfur treatments were followed in August by hydrogen cyanide fumigation, the populations of mature scales the following spring were materially reduced below the levels occurring the year previous. In most cases where fumigation alone was applied the populations of maturing scales became higher than the year before.

Sulfur dust applied during May and June caused very high mortalities of the citrus red mite at Placentia in 1937 and at North Whittier Heights in 1939.—1-6-42.

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NEWELL CLUB MEMBERS IN THE SERVICE

The following members of the Newell Entomological Society of the University of Florida, Gainesville, are reported to be serving in some branch of the armed services of the United States. Details of their military status will be published from time to time as they may become available.

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Control of the Brown Snail in Citrus Orchards

H. C. Lewis and J. R. La Follette, *California Fruit Growers Exchange, Los Angeles*

Damage to citrus trees in certain coastal areas of southern California by the European brown snail, *Helix aspersa Müller*, has at times ranked in importance with injury caused by insect pests. While snails have been of concern to citrus growers in varying degrees for many years, damage to fruit and foliage has greatly increased during the past two or three seasons. A number of factors have contributed materially to these recent outbreaks, the most important being relatively mild winters with prolonged heavy rainfall. More moderate summer weather and the tendency toward less soil cultivation with accompanying increase of weed and grass growth also have encouraged snail development. Furthermore, snail control has been complicated by lack of standardized materials, methods and seasonal timing.

Control Methods Used.—Control measures used in citrus orchards have consisted largely of the application of poison baits. Ducks have also been used. Occasionally growers have resorted to hand picking. Spraying or dusting citrus trees with stomach poisons or repellents has received little consideration. A state regulation prohibits the sale of arsenicals for use on citrus. Materials in common use such as oil sprays, cryolite and copper sulfate have been tried without effective results. Recently, Paul Andres, an agricultural inspector in Orange County, has obtained a high degree of mortality with a spray of tartar emetic, a material widely used in thrips control.

Control as Related to Habits.—The habits and seasonal development of snails, as well as temperature and humidity conditions, have a very important bearing on the success or failure of control measures. Throughout the summer and fall months when temperatures are high and relative humidity low, most of the snails are in the adult stage, inactive, and generally sealed down on the main trunks and larger limbs and protected by the heavy foliage characteristic of citrus trees. Little feeding takes place during this hot and dry season although heavy fogs or heavy irrigations result in more or less snail movement from the trees to the ground. Snail control measures in summer are only partially effective. The period of greatest snail activity is the rainy season, starting in the winter and continuing through the spring months, during which time the pest, particularly the immature stages, remains in the true feeding on fruit and tender foliage. Broadcasting poison bait onto the tree during these months is usually necessary to prevent further damage. Where the cover crop is heavy, it is often well populated with snails until it becomes dry or is turned under. The most effective control where a cover crop is present is usually secured by baiting immediately following the turning under of the cover crop.

Types of Baits.—Several types of snail baits have been used in citrus orchards. Basinger developed the use of the calcium arsenate-bran formula prepared by mixing 1 pound of calcium arsenate with 16 pounds of moist flake bran. Such a bait can be home-made, mixed according to the above formula, or purchased commercially. With the introduction of metaldehyde for snails in recent years, a second type of bait, one in which metaldehyde has been substituted for the calcium arsenate usually at a strength of about 2.75 per cent, has been placed on the market. A third type, including both calcium arsenate and metaldehyde and known as combination bait, has also been widely used. The method of application has been generally to broadcast the straight arsenical baits over the tree.

Table 1.—Relative effectiveness of commercial snail baits applied in summer. Six weeks duration.

Type of Bait	Applied As Ring Around Trunk and Piles At Skirts—Per Cent Dead	Broadcast Over Trees—Per Cent Dead
Calcium Arsenate	83	77
Metaldehyde	66	34
Metaldehyde & Arsenate	61	28

Mean number of snails per tree was 248 ± 13.

Metaldehyde bearing baits are generally distributed in small piles under or around the tree. The uncertainty of the comparative value of these different baits led to a series of experiments to obtain information as to their relative effectiveness at different seasons of the year.

Table 2.—Relative effectiveness of commercial snail baits applied during fall months. Eight weeks duration.

Type of Bait	Applied As Ring Around Trunk and Piles At Skirts— Per Cent Dead	Broadcast Over Trees —Per Cent Dead
Calcium Arsenate	90	73
Metaldehyde	73	65
Metaldehyde & Arsenate	77	65

Mean number of snails per tree was 164 ± 12.

In this test, groups or blocks of trees each composed of 6 to 10 trees were treated twice following successive irrigations about 3 weeks apart during August and September. It is during this season of the year that most snails are adults, resting dormant on the trunks and larger limbs, and the time of year when control is most difficult. Calcium arsenate baits appeared to be somewhat superior to metaldehyde baits.

The above orchard test was repeated, this time with 3 applications during September, October and November, a period when snails are still inactive and difficult to kill.

In the second test weather was first hot and dry, then rainy and cool. Calcium arsenate baits were somewhat superior to metaldehyde. Rain apparently adversely affected the calcium arsenate-bran bait when broadcast.

Results of the same test repeated during rainy, cold weather in January are shown in table 3.

Rain fell during much of the duration of the January test. Fresh-pressed by-product orange pulp was as effective as bran distributed in trunk ring and piles, and when broadcast, was more effective in wet weather than was bran. Arsenical baits were definitely superior to metaldehyde baits.

Arsenical Baits.—Orchard tests, as well as field experience, have indicated that the different types of baits have performed differently in the various seasons of the year due to the condition of the snail populations as well as to the weather. Under the conditions prevailing in southern California citrus groves, properly applied commercial baits containing calcium arsenate have generally proved superior to metaldehyde-bearing baits regardless of time of year. In general, arsenical baits during the summer and autumn, when most snails are mature, have been equally effective whether broadcast or applied in a ring about the trunk or in piles under the tree. In winter and spring, when young snails usually remain on the tree, broadcasting over the tree is most effective and usually is necessary to stop damage immediately.

Metaldehyde Baits.—In the summer, baits containing metaldehyde alone have given about the same control as those with both metaldehyde and calcium arsenate, indicating that the effect upon snails was entirely from the metaldehyde when temperatures were high. Under cool conditions, combination baits of arsenic and metaldehyde proved more effective than metaldehyde alone, but not so good as calcium arsenate alone. When broadcast during the summer, the combination bait and the straight metaldehyde bait both gave a poor kill, indicating that under certain conditions metaldehyde is not only ineffective but repellent as well. Piles of material containing metaldehyde only,

Table 3.—Relative effectiveness of a single application of baits in January including fresh-pressed orange pulp. Twelve days duration.

Type of Bait	Applied As Ring Around Trunk And Piles At Skirts— Per Cent Dead	Broadcast Over Tree —Per Cent Dead
Orange (Fresh-Pressed) and Calcium Arsenate	71	72
Bran, Calcium Arsenate	73	58
Bran, Metaldehyde	25	
Bran, Metaldehyde and Calcium Arsenate	59	

Mean number of snails per tree was 129 ± 9.

placed near the tree trunks in the summer or fall where constant shade prevails, resulted in about a 50 per cent kill of those snails accumulated on the material in 2 weeks time, whereas in the winter none was killed in 2 weeks time. Metaldehyde baits have been found to be most effective when placed in small piles in direct sunshine. There is some evidence that large piles of metaldehyde baits placed in the shade will kill snails more slowly than arsenical baits and have some cumulative effect over a long period of time in reducing the snail population.

Only under certain highly favorable conditions, such as when used on relatively small trees where some direct sunlight reaches the tree trunks, have metaldehyde baits given good commercial control. If used at all, it would seem that metaldehyde baits should be employed only during the warmer part of the year, being applied in small piles exposed to some direct sunshine, and during foggy weather or immediately following irrigations. The accumulation of dead or moribund snails on piles of metaldehyde bait is likely to be impressive but misleading. Snails killed by calcium arsenate do not accumulate on the bait but are scattered and often secreted under leaves and debris or even dying stuck tight to tree limbs. Orchard tests have indicated, under most circumstances prevailing in southern California, that when the entire snail population over a block of trees is considered, metaldehyde baits are inferior to straight arsenical baits. Slugs, on the other hand, not normally injurious to citrus, are much more readily killed by metaldehyde than by commercial arsenical snail baits.

FRESH-PRESSED ORANGE PULP.—The evidence obtained by means of orchard trials, as indicated above, showed that arsenical baits are more effective than other types of baits generally used in citrus groves. Tests were then made of materials which might be used in place of red flake bran, including fresh-pressed orange pulp. The use of citrus by-products for bait work with grasshoppers or snails is not new. However, non-dehydrated pressed orange pulp, produced in present day by-product plants, is believed not to have been used previously in snail control. In citrus by-product plants, juice concentrates, orange oil, pectin and other materials are extracted from cull fruit. The remaining pulp is ground, treated, pressed and dried for cattle feed, selling locally at somewhat less than the price of bran. This dried pulp has been used to some extent in the past in place of bran by growers, partly because it is slightly cheaper. Trials with this dried material, not to be confused with fresh non-dehydrated pulp, were made which indicated it to be somewhat less effective than bran. The dried product is the same material as the non-dehydrated except that it has gone through a furnace type drier losing much of the fresh orange character. Drying is also expensive, increasing the cost of pulp from about eight to over thirty dollars per ton. This fresh-pressed orange pulp contains about the desired amount of moisture, is not sticky and broadcasts freely. Calcium arsenate is mixed with the pulp direct at the rate of 4 or 5 pounds per 100 pounds of pulp. Cement mixers or mortar boxes have been used for mixing. When compared with bran as the basis for snail bait, it has proved to be about equally effective, even though used at the rate of 8 to 12 ounces naturally moist compared to 8 ounces dry bran plus sufficient water to moisten. Numerous tests indicated the fresh pulp to be about as effective as bran in initial kill and there is some evidence that the small pieces of orange retain their effectiveness much longer in the field than bran. Especially is this true under rainy conditions when orange pulp is particularly effective; a single application having been observed almost to eliminate the pest. With present prices prevailing, non-dehydrated pressed orange pulp costs about one-fourth as much as bran and is fully as effective on snails.

Following the experimental work done with orange pulp during the winter and spring of 1941, growers were encouraged to make use of this bait. During the season 110 tons of fresh-pressed orange pulp was used for snail bait which covered between 2000 and 3000 acres this first season of use. Cooperative pest control associations have been the chief handlers, one association treating about 900 acres and another close to 600 acres. Cost to the grower, including material and application, has been two dollars per acre or less. Application is made by broadcasting the material by hand onto the trees, usually from a truck driven between the tree rows.

There are some drawbacks to the use of fresh-pressed orange pulp. It can be obtained only from citrus by-product plants. It is relatively perishable, although it can be held for a few days or a week. However, where some organization, cooperative or otherwise, desires to handle such a product, an effective and very cheap snail bait is available. Like any other bait, it should be used only when snails are active, preferably during the late winter and spring months.

SUMMARY.—Poison baits consisting of bran, or substitutes, with calcium arsenate or metaldehyde, alone or in combination, have been used for control of the European brown snail in California citrus orchards. Orchard experiments and observations have shown that:

(1) Arsenical baits are somewhat more effective than metaldehyde baits.

(2) Metaldehyde baits are relatively ineffective when broadcast and are less effective during cold weather. When used they should be placed in small piles in the sunshine.

(3) The season for best control is rainy weather in late winter and spring when snails are most active.

(4) Arsenical baits should be broadcast onto the trees, and this method of application is essential during the period when greatest tree damage is being done by immature snails.

(5) Fresh-pressed orange pulp, a citrus by-product, with calcium arsenate, is the most effective bait yet tried.—1-6-42.

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Lime Zinc Spray as a Repellent for Leafhoppers on Citrus

H. C. LEWIS, *California Fruit Growers Exchange, Los Angeles*

In recent years, the potato leafhopper, *Empoasca fabae* Harris, has become an important pest of citrus in the San Joaquin Valley of California, the damage being confined to this northern citrus district. Numerous summer host plants of this insect, including cotton, potatoes, alfalfa and others, are grown extensively in the San Joaquin Valley areas. During the fall the leafhoppers migrate presumably from these cultivated as well as wild host plants particularly wild sunflower into the warmer citrus groves to spend the winter. Southern California citrus areas, geographically distinct from central California, have not been subject to attack by the leafhopper.

It is of interest to note that the problem on citrus is caused entirely by overwintering adults, whereas generally, and particularly in the eastern states, this insect is a problem on field and truck crops in the growing season. On citrus no immature forms are concerned, the problem being one of controlling migrating adults only.

Fruit spotting was observed in central California and first associated with *Empoasca fabae* in 1937. There have been unconfirmed reports of occasional damage in previous years. Light injury to fruit in the season of 1930–31 was observed, although it was not known at that time what was responsible. No commercial injury occurred from 1931 to 1937. Leafhoppers migrating into groves in the fall of 1937 damaged fruit during the following winter. In the fall of 1938, a series of orchard tests were conducted from which it was determined that a light whitewashing effectively repelled the overwintering adult hoppers. The three succeeding seasons, including 1941, have witnessed increasingly heavier fall migrations into orange groves, necessitating increased spraying each year. Acreage treated has increased from about 700 acres in 1938–39 to about 4000 in 1940–41, or about 10 per cent of the total citrus in Tulare, Fresno and Kern counties. During the fall of 1941, migrations have been in larger numbers than in any previous year and whitewashing for

the present season (1941–42) is much more general than previously.

MIGRATORY HABITS AS RELATED TO CITRUS.—Migration to the citrus orchards takes place with the advent of cool weather and the drying of the numerous cultivated and wild summer hosts. Citrus orchards are located along the foothills of the Sierra Nevada and generally are in the warmest locations of the San Joaquin Valley. The relatively heavy foliaged trees themselves afford additional protection during the winter. This movement commences in September and continues through October and November, possibly later. These adult hoppers remain in the orange groves until about March 1, when they return to summer hosts. Hibernation of adults of *Empoasca* is not complete since they feed on ripening orange fruits, although during cool periods activity is much reduced.

The migratory habits of the potato leafhopper this past season have clearly shown the difficulty of forecasting severity of infestation and damage. For several years the heaviest migration into citrus groves has been in early October. Leafhoppers were somewhat lighter than normal in central California orange orchards during September and October. In early November, during an extended period of hot weather which dried out the cotton and other summer hosts, hoppers migrated into citrus orchards in greatly increased numbers. As a result, more damage than usual, particularly to navels, occurred during November.

Certain individual orange groves have been injured, whereas others are not affected at all or only slightly so. As a rule, the same orchards are infested year after year by overwintering hoppers. Certain orchards are more affected because of geographical location or nature of tree growth. Generally speaking, orchards located along the west side of the citrus belt adjoining the valley areas given to field crop culture are the ones earliest and most seriously injured. Large trees or closely set trees are usually affected. Vigorous, well cared for groves are preferred by hoppers to weak, sparsely foliaged trees, presumably because of the better protection for hibernation. Fruit on young or small trees is not often damaged.

NATURE OF INJURY.—Injury caused by *Empoasca fabae* is by spotting ripening fruits. As soon as oranges begin to break in color from dark green they are susceptible to attack but they are not injured while green. This spotting or blemish on the fruit is known as "oleocellosis" or rind-oil spot, which is considered to be an injury caused by the release of orange oil occurring naturally in the rind of the fruit. While in no way affecting the interior or eating quality of oranges, these rind-oil spots are blemishes which detract from the appearance of the fruit, thereby reducing the value. The oil spots are presumed to be entirely caused by rind oil released as the result of feeding punctures of *Empoasca*. There is no evidence that they are the result of any toxic action. Rind-oil spots may also be caused by other means which mechanically injure ripening fruit such as rough handling and frosts. Damage has been confined entirely to fruit with none to the trees except in one or two extreme cases when burning of new foliage occurred as the result of hopper feeding. Navels are attacked first, injury appearing about October 1 and gradually increasing until the fruit is picked. Valencias begin to show injury about the first of November, or a month later than navels, and are marked more severely than navels since the valencia fruits remain on the tree throughout the winter. Also, the spot on valencias is much more of a blemish, as with age it becomes dark in color. Lemons and grapefruit are not affected to any commercial extent.

CONTROL MEASURES.—Control of *Empoasca* brought about by the application of a light whitewash consisting of lime and zinc has in general been very satisfactory. Since the migration into groves extends over a period of two or three months, a repellent spray appears most suitable and cheap. Some drawbacks are characteristic of a repellent. Treating part of a grove is of no value generally since whitewashing forces the leafhoppers onto untreated areas or into other untreated groves. However, the use of a contact insecticide such as pyrethrum or cyanogas is more expensive, especially as repeated treatments would likely be needed to maintain a grove free of migrating adult hoppers.

Whitewashing with hydrated lime and zinc sulfate is carried out in the case of valencias at the rate of 33.3 pounds of hydrated lime, 5 pounds of zinc sulfate plus casein spreader 0.67 pounds, or fish

oil 1 pint, per 100 gallons of spray. In the case of navels, the amount of lime is reduced somewhat since the required protection period is shorter.

No ill effect has been observed to result from repeated applications of the above formula. It should be emphasized that but one spraying is applied each year and this spraying is in the fall or early winter during cool weather, which is also the beginning of the rainy season. The spring flush of new growth appears before any warm weather is experienced the following season. Some orchards have had four whitewashings in the past four years and show no indication of any injury to trees or crop. However, there has been some apprehension that repeated application of hydrated lime might have a desiccating effect. While no evidence of such has occurred in the field, some substitute whitewash materials have been tried experimentally. Talc in place of lime was suggested by Dr. A. M. Boyce. Of a number of combinations tried, the only promising formula consists of 30 pounds talc, 3.3 pounds hydrated lime, 5 pounds zinc sulfate plus spreader per 100 gallons. This resists weathering by winter rains almost as well as the lime zinc formula but has not been proved by commercial use.

The whitewash residue on citrus trees in central California has not resulted in the increase of scale or other citrus insects. In this area the only insects requiring treatment besides the potato leafhopper are citrus thrips, *Scirtothrips citri* (Moult), citricola scale, *Coccus pseudomagnoliarum* (Kuw) and yellow scale, *Aonidiella citrina* (Coq.). None of these insects has increased because of whitewashing.

Zinc sulfate not only tends to bind the lime and increase the white deposit but also is of value in correcting mottle-leaf which is a zinc deficiency disease affecting citrus. Most orchards in central California require annual application of zinc, and whitewashing for leafhopper fills this requirement. Zinc performs a third function in reducing injury by septoria, a fungus disease which affects valencias during winter months to some extent in central California. In some cases, 1 pound of copper sulfate is added per 100 gallons to the usual lime-zinc formula for more certain septoria control. In this way whitewashing citrus trees serves the purpose of controlling leafhoppers, mottle-leaf and, in the case of valencias, septoria. For leafhopper control whitewashing need be applied only as a light outside application. Cost averages about eight dollars per acre.

SUMMARY.—The potato leafhopper, *Empoasca fabae* Harris, has become an important pest of citrus in the San Joaquin Valley of California. Injury to ripening oranges is caused by leafhoppers in puncturing the rind of the fruit resulting in a blemish.

Only overwintering adult leafhoppers are present during the winter months when injury takes place. No immature forms of the insect occur on citrus.

A light whitewashing composed of zinc and lime effectively repels the migrating adult hoppers. This whitewashing has been widely used the past four years.—1-6-42.

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DR. CUSHING JOINS THE ARMY

Dr. Emory C. Cushing, formerly Chief of the Division of Insects Affecting Man and Animals in the Bureau of Entomology and Plant Quarantine, has accepted a commission as a Major in the Sanitary Corps of the United States Army. Dr. Cushing is probably best known for his part in the recognition of the primary screwworm.

Life History of *Diaspis boisduvalii* and Its Control on Cattleya with Calcium Cyanide

RICHARD M. BOHART,[1] *University of California, Los Angeles*

Boisduval's scale, *Diaspis boisduvalii* Signoret, is one of the most common pests attacking cattleya grown under glass.In California it is by far the most abundant of the several species recorded. A severe infestation in a large commercial planting came to the writer's attention in August, 1940, leading to observations on life history and control which are here presented.

The fact that *Diaspis boisduvalii* is the only *Diaspis* with distinct prosomatic lobes which occurs on orchids makes identification relatively simple. Records of *D. boisduvalii* from Cocos palm, *Arecastrum romanzoffianum*, were referred by Ferris (1937) to *D. cocois* (Lichtenstein). Unsuccessful attempts were made by the writer to transfer crawlers from cocos palm to cattleya leaves. In heavy infestations of *D. boisduvalii* the leaves of cattleya become encrusted and take on a striking cottony appearance. Leaves in this condition soon turn yellow and die. However, only a few scales are necessary to demonstrate a marked toxic effect. Within a few days after a crawler settles, the surrounding area becomes chlorotic with a diameter many times that of the insect. Subsequently the spot slowly enlarges as the scale grows. The long mouthparts (7 times the length of the body of the adult female) may partially account for the relatively large chlorotic spot. Crawlers settle on every part of the leaf but they show a preference for the declivity along the midrib and for the upper part of the petiole which is loosely covered with a thin sheath. The following observations on the life history were made in the laboratory on potted cattleya at an average temperature of 75° F. (72° to 78° F.) and high humidity.

Egg.—The colorless translucent appearance of the eggs as they are freshly laid under the protecting armor of the female changes gradually to pale yellow and then to pale orange shortly before hatching. The oviposition period was determined by removing eggs from the vagina of a female, which was induced to lay rapidly by severing the stylets. Of the nine eggs obtained in this fashion one hatched in 5 days, one hatched in 6 days and seven hatched in 7 days. In another test 100 eggs were taken at random from 10 females. At the end of 7 days these had all hatched. The empty egg shells are white, shriveled, and roughly triangular.

First instar nymph.—The newly emerged pale orange young average 0.18 mm. in length and 0.10 mm. at the widest point, excluding appendages. They wander over the plant for a period not exceeding 2 days. The majority settle within 24 hours. During this time they readily move from plant to plant if the leaves are touching. Eventually the young scales stop and insert their stylets into the plant. This usually marks the beginning of the nonmobile period, but if the scales are disturbed, they may move to another spot.

The day after settling, the body flattens. The long filaments, which are given off continuously during this instar, appear posteriorly and curl up over the body. On the fourth day after settling, a thin wax film becomes visible stretching forward over the dorsum from the rear. By the seventh day after settling this film has covered the posterior three-quarters of the body and the scale takes on a translucent appearance. Up to this time it is not possible to differentiate between the sexes, but shortly before molting the males begin throwing off powdery wax in two masses at the posterior end of the body. These masses build up over the back to some extent. The female continues until molting to send out long filaments but no powdery wax. The males were observed to molt 9 days after settling and the females occasionally molt a day earlier. The fully grown first instar nymph attains a length of about 0.33 mm. and a width of 0.22 mm.

Second and following instars in the male.—Immediately after molting, a posterior growth begins in the male with the laying down of powdery wax concentrated in longitudinal ridges so as to give a tri-

[1] The writer wishes to acknowledge the assistance of R. J. Pence in working out details of the life history.

carinate appearance. After one day this equals one-quarter the length of the exuvium. After 2 days it extends two-thirds the length of the exuvium, twice the length after 3 days, and two and one-quarter times after 4 days. Full size is attained at this time but powdery wax is still given off. The second and third molts are not visible beneath the armor.

On the 11th day after the first molt, caudal filaments and legs are visible when the posterior armor is lifted. The wings are not fully developed, however, until 2 days later. On about the 15th day after the first molt, or 33 days from the date of egg-laying, the adult male emerges by backing out from under the armor. It stretches for a few minutes and then flies away. In rearing scales on cut leaves placed in small dishes of water under large glass jars it was observed that the males invariably became caught in the water, none of them dying elsewhere in the jar. No copulation was noted under these conditions although hundreds of males were produced and sooner or later collected on the surface of the water.

The adult male averages 0.91 mm. in length excluding the antennae. The antennae average 0.55 mm. in length. The antennal flagellum is 8-segmented, all except the last segment being more than 4 times as long as broad and with bristles which are two-thirds as long as the segments.

Second instar female.—The young second instar female differs from the previous instar in being slightly elevated and surrounded by a small flange. As it retains the skin of the first instar as a covering, the loss of the antennae, legs, and caudal stylets is not immediately apparent. Two days after molting, the marginal flange, which is laid down by the scale with a circular pivoting motion, is a prominent feature. The body of the scale expands slowly until by the seventh day it nearly fills all the space beneath its armor. Molting then takes place, becoming complete on the eighth day. At maturity the length averages 0.52 mm. and the width 0.37 mm.

Third instar female.—The marginal armor is only slightly evident for some time after molting. It is produced gradually over a period of 4 to 5 weeks before oviposition. Just prior to this event the body humps slightly and the armor takes on a bowed appearance. The complete cycle from egg to egg takes approximately 50 days on an average. Counts made at various times indicate that a single scale is capable of producing approximately 200 eggs. These hatch and the young crawlers either find their way out from beneath the armor or in some cases establish themselves under it.

POPULATION INCREASE STUDY.—An attempt was made to determine roughly the rapidity with which an infestation of this scale might increase. A leaf, which had broken below the pseudobulb and had partially sealed itself off, was cut and placed in a moist chamber. The temperature averaged 75° F. throughout the experiment. Ten crawlers established themselves on the leaf on September 17, 1940 and seven of these proved to be females. On November 14, 1940 the first female began laying eggs. These females were circled with india ink to distinguish them from their offspring which were also given distinctive marks. In the second generation 43 females reached the oviposition stage about January 2, 1941. In the third generation 250 females reached the same stage about February 14, and in the fourth generation 573 females attained this status about March 29, 1941. At this time the total number of females including the off-brood individuals was 5,355. The exact number of males could not be counted but approximately 5,000 were present. From these figures an approximate rate of increase for females of 9:1 can be calculated for each successive generation. Deterioration of the leaf caused the study to be abandoned on April 30, 1941 before the fifth generation reached maturity. At this time one of the original 7 females, more than 7 months old, was still alive.

CONTROL.—The use of HCN gas in control of cattleya insects was reported by Sasscer & Dietz (1918). They found that orchids in good condition were not seriously affected by treatment in a sealed container with 1 ounce of NaCN to 100 cubic feet for 1 hour under a vacuum of 20 inches. Sasscer & Weigel (1924) recorded the first work using calcium cyanide dust in greenhouse fumigation and Weigel (1925) followed this up with a more complete report. Weigel supervised the fumigation of large orchid houses for 12 to 15 hours with 1 ounce of granular CaCN per 1,000 cubic feet. The results were a 100 per cent mortality of *Diaspis*

boisduvalii and 52 per cent mortality of *Parlatoria proteus* Curtis. No injury was observed on cattleya including some plants in flower.

In spite of the apparent tolerance of cattleya under certain conditions for high concentrations of cyanide gas, injury from its use has been reported by growers from time to time. In the "Cyanogas Handbook" (1936) the following statement is made with respect to calcium cyanide fumigation of orchids for scale. "Although some growers have fumigated *Cattleya* and *Oncidium splendidum* with 0.25 ounce per 1,000 cubic feet, and in some cases using a dosage as high as 1 ounce per 1,000 cubic feet; fumigation of these varieties is not recommended, since they seem to be particularly susceptible to the gas."

In addition to cyanide fumigation two other types of treatment are used at the present time by orchid growers. The first of these involves the use of a spray which usually contains water-miscible pyrethrum extract as its basic ingredient. The second is the "brush" method in which a crew of workers is sent through the greenhouse to wash the scale off the leaves with paintbrushes dipped in solutions of pyrethrum or nicotine sulfate. The degree of control attained by either of these treatments is not satisfactory if the scales are growing under conditions favorable to rapid multiplication. In addition, the cost is high, especially with the second method.

In 1940 the writer was afforded an opportunity to assist in the control of a severe infestation of *Diaspis boisduvalii* in a large cattleya nursery. Previous attempts at control by the spray and brush methods outlined above had proven entirely unequal to the situation. Due to the fact that the orchids were being grown under unusually warm and humid conditions, the grower had hesitated to use calcium cyanide for fear of injury. In order to determine the injurious effects of low concentrations, dosages of 0.067 ounce, 0.1 ounce, and 0.125 ounce of granular calcium cyanide[1] to 1,000 cubic feet were used in overnight fumigations. During the 12 hour periods of treatment the temperature range was 72 to 62° F. and the relative humidity varied from 85 to 90 per cent. The plants were "dried out" for three days before each fumigation by withholding water. The calcium cyanide was sprinkled "salt shaker" fashion along the gravel walks, the surface of which was dry.

The amount of injury varied greatly on different plants. Orchids which had recently been repotted or which were weak for some other reason, occasionally showed severe cyanide burn. Much more extensive injury resulted from the fumigation at 0.125 ounce than at 0.10 ounce. Also, the degree and appearance of injury was markedly different on plants of different parentage. In general the most susceptible plants were the slow-growing types. In all cases the older leaves were more severely burned than the younger ones, and flowers were apparently unaffected.

The most common type of injury consisted of irregular dark purplish blotches on the upper sides of old leaves. Very severe symptoms of this type occurred on a cross between *Cattleya dowiana* and *C. bicolor*. An odd type of injury was noted on plants of *Cattleya trianae*×*Laeliocattleya marie dobrott*. On the upper side of old leaves of mature plants, large areas turned whitish brown or whitish green. Unexpectedly, where scales were present the normal green color of the leaf remained in a circle about each scale. Examples of this cross which were younger than 4.5 years were not affected. On *C. trianae* alone a peculiar speckled injury occurred covering most of the undersurface of old leaves. No decrease in the vigor of these plants was noted. In fact, except in rare cases none of the types of injury appeared to cause more than a temporary setback of the affected orchids.

The control of adult female scales by calcium cyanide fumigation is summarized in table 1. Counts were made at random in the greenhouses several days after fumigation and the dead females were easily separated by their dark brown color from normal yellow specimens. It was early found that practically 100 per cent of the first and second instar females were killed by a dosage of 0.10 ounce per 1000 cubic feet, and subsequent checks were made of third instar females only. At 0.067 ounce per 1000 cubic feet a mortality of only 37.3 per cent was achieved in a single test. At 0.10 ounce 81.7 per cent of the mature females were found dead, and at 0.125

[1] A commercial product known as *CYANOGAS G-FUMIGANT*, stated to contain not less than 40 per cent and not more than 50 per cent calcium cyanide.

ounce the mortality was 84.4 per cent. Fumigations on successive weeks were also tried with much higher cumulative kills. Two successive treatments in one greenhouse at 0.10 ounce gave a mortality of 97.6 per cent. A similar experiment in another greenhouse substituting 0.125 ounce for the second dosage gave 96.9 per cent. A count made in the latter greenhouse after a third fumigation a week later at 0.10 ounce gave a mortality of 98.4 per cent. Weekly fumigations were continued by the grower for a total of seven weeks. At the end of this period, live scales were extremely rare and these were located under the tightly-fitting sheath at the base of the stem. No further treatments were made until four months later when large numbers of first and second instar scales appeared on the leaves. Occasional subsequent fumigations were made using the 0.10 ounce dosage for three successive weeks and the number of scales was kept at a very low point without undue injury to the plants.

SUMMARY.—*Diaspis boisduvalii* Sign. is one of the most common pests attacking cattleya. It is the most abundant and injurious of the several species of scale recorded in California. From life history studies conducted in the laboratory at 75° F. and high humidity it was found that the complete cycle from egg to adult male averaged 33 days and from egg to egg-laying female averaged 50 days. About 200 eggs were laid by a single female. In a study of population increase on an orchid leaf in the laboratory, approximately 10,000 scales, of which 50 per cent were females, were produced over a period of 5 months by seven original specimens. Effective control was obtained by use of dosages of granular calcium cyanide as low as 0.10 ounce per 1000 cubic feet. Fumigation for 3 successive weeks reduced the scale population by 98.4 per cent. A small amount of injury in the form of leaf burn occurred on the older leaves, especially in the slow-growing varieties.—1-6-42.

Table 1.—Effect of low concentrations of calcium cyanide gas used in overnight fumigation of Diaspis boisduvalii.

Number of Weekly Fumigations	Number of Ounces of 40 Per Cent Calcium Cyanide per 1000 cu. ft.			Number of Females Examined	Number of Dead Mature Females	Per Cent of Dead Mature Females
	first week	second week	third week			
0 (check)	—	—	—	301	22	7.3
1	1/15	—	—	204	76	37.3
1	1/10	—	—	721	589	81.7
1	1/8	—	—	1292	1091	84.4
2	1/10	1/10	—	1296	1265	97.6
2	1/10	1/8	—	1896	1837	96.9
2	1/10	1/8	—	338	165	48.8[1]
3	1/10	1/8	1/10	957	942	98.4

[1] This count was made in a particular section of one greenhouse. It was also found that frogs, which were readily killed in other parts of the greenhouse during the fumigation, were unharmed in this section.

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Commercial Control of the Pepper Weevil in California

ROY E. CAMPBELL and J. C. ELMORE, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

The season of 1941 presented an excellent opportunity for observations on the results obtained by growers on the control of the pepper weevil, *Anthonomus eugenii* Cano, in southern California. The winter of 1940–41 was mild, permitting large numbers of weevils to survive. Active adults were observed throughout the winter on nightshade and were so numerous early in the spring that seed beds as well as early-planted fields became heavily infested. Heavy spring rains delayed field planting for at least a month, so that even blossom buds became infested before pods began to set. As a result of these conditions the weevils soon built up to destructive numbers and continued as a serious menace to peppers throughout the season. Two pepper fields in the Garden Grove area were plowed up early in the season because of total loss caused by the weevil.

INSECTICIDES USED.—Previous experiments had demonstrated that calcium arsenate and cryolite were the only insecticides effective enough to control the weevil, but the use of calcium arsenate in 1940 had resulted in heavy infestations of aphids, *Myzus persicae* (Sulz.), causing considerable defoliation of plants. In addition, the presence on the pepper pods of honeydew excreted by the aphids and the growth of sooty mold fungus on this honeydew made the removal of poisonous residue difficult. In the few fields where cryolite was used in 1940 the increase in aphid populations was so slight that no damage was caused. Hence, in 1941 cryolite was used almost exclusively. Several growers used calcium arsenate for the first dusting, but when they observed aphid infestations developing rapidly they switched to cryolite. One grower used pyrethrum. Since most of the growers used cryolite, the study of the results obtained was much simplified.

Natural cryolite containing 90 per cent of sodium fluoaluminate was the material most commonly used. This was mixed with equal parts of diluent, by weight, to give an active strength of 45 per cent sodium fluoaluminate. The diluent in most cases was finely ground talc, but one company used finely ground volcanic ash for this purpose. To reduce the tendency to cause an aphid-population increase, enough cube powder was added to give 0.5 per cent of rotenone in the final dust mixture. When calcium arsenate was used, the same quantity of cube powder was added.

The recommended quantity of dust mixture was 15 pounds per acre. In most cases a smaller quantity was used for the first two dustings, when the plants were small, and 20 to 25 pounds for later dustings, as the plants grew larger. The average of all the dustings ranged from 15 to 20 pounds per acre per application. On good soil, where the plants grew very large, 20 to 25 pounds per acre was required to obtain proper coverage.

TYPES OF DUSTERS USED.—Power dusters mounted on tractors or on two-wheeled carts and covering four to six rows were most commonly used. Fan-type hand dusters were used on uneven land or in odd-shaped fields. These dusters were all satisfactory when properly adjusted.

Several trials of airplane dusting were made, but none was entirely satisfactory, and it was found necessary to increase the quantity of the dust mixture applied per acre by 50 to 100 per cent to approach the efficiency obtained by ground dusters. This, of course, materially increased the cost of airplane dusting.

RECOMMENDED CONTROL METHODS.—Recommendations for pepper weevil control were as follows:

Pepper fields should be frequently examined early in the season, and, if a given field or adjoining fields are found to be infested, treatment should begin when the first pods begin to set and continue until most of the pods are mature.

Three applications should be put on at 4- to 5-day intervals. Then, unless the weevils are numerous in the locality, a 10-day interval was suggested, followed by three more applications at 5-day intervals.

In most fields this is a sufficient number of dustings but, if small pods are still being produced which might become in-

fested, one or two more dustings may be necessary.

This program was adhered to by many growers, but with others it was varied somewhat. Occasionally irrigation interfered with dusting, so that the interval was 2 to 5 days longer than recommended. Most growers dusted five times, a few less, and some seven to nine times.

RESIDUE REMOVAL.—All growers, agricultural agencies, and insecticide dealers who had any connection with the pepper industry were warned that poisonous insecticides such as calcium arsenate and cryolite should not be used on peppers unless facilities were available for washing off the poisonous residue. Pepper growers with no previous experience in pepper washing were referred to the California State Bureau of Chemistry for information concerning successful methods of residue removal. Improved washing equipment, which was thoroughly tested last year, has made it possible to remove poisonous residues from peppers successfully by the use of agitation in a warm hydrochloric acid bath.

PROCEDURE.—The criterion selected for comparing treated and untreated fields in this study was the number of pods per plant. Fields or portions of fields which obviously had low production, owing to causes other than pepper weevil injury, were omitted from the survey. The mean number of pods per plant for each field was obtained by counting all the pods on 40 plants near the center and near each corner of the field. In order to eliminate the possibility of bias in selecting the plants, the observer walked down a row until the tenth plant was reached. The pods were counted on the tenth and eleventh plants. From this point the observer moved across to the next row and followed it in the same direction to the tenth plant, and so on until 40 plants were examined in each of the 5 areas of a field. Altogether, 46 fields were examined.

Since the majority of the fields were planted to Mexican chili peppers, most of the counts were in fields of this variety. However, there were enough fields of both California chili and paprika peppers so that counts in these could be included. The Mexican chili pepper produces fewer pods per plant than the California chili or the paprika pepper.

Table 1.—Pepper production as influenced by three or more applications of cryolite dust for the control of the pepper weevil.

Variety of Peppers	Condition of Field	Number of Fields	Acreage	Average Number of Pods per Plant: Highest-Producing Field	Lowest-Producing Field	All Fields
Mexican Chili	Dusted	19	976	21.6	4.8	13.8±1.1
	Undusted	11	179	7.8	0.04	3.6± .8
California Chili	Dusted	6	310	31.5	10.4	19.9±3.7
	Undusted	1	10	4.6	4.6	4.6[1]
Paprika	Dusted	4	175	39.3	34.5	36.9[1]
	Undusted	2	30	15.0	13.5	14.2[1]

[1] Standard error not calculated because of small number of fields.

RESULTS.—The data in table 1 show that when three or more applications were made, cryolite was effective in preventing pepper weevil damage to the pods. The Mexican chili fields that were dusted had an average of 10.2 more pods per plant than the undusted fields. The best treated field produced 13.8 more pods per plant than the best untreated field.

The California chili is very susceptible to the pepper weevil, and, moreover, it is easy to remove poisonous residue from this variety. For these reasons only one California chili field was found which was untreated. Since it is a common practice to pick green chilies of this variety for the local market and for canning, only a few fields were found in which a count of the total number of pods could be made. The difference between the number of pods per plant in the treated fields and the

number in the untreated field was even greater than was the case in the Mexican chili fields.

The six fields of paprika peppers included were all planted at about the same time. The four fields which received nine application each had more than two and a half times as many pods per plant as the two fields which were untreated.

EFFECT OF NUMBER OF APPLICATIONS.—Successful pepper weevil control requires plant protection during the entire pod-setting period because pods are susceptible to attack until they are mature. This involves frequent applications throughout the season, beginning, in the case of early infestations, when the first pods begin to set. If insecticide applications are started at the correct time, but not continued long enough, or if too long intervals occur between applications, many pods become infested. The loss of late pods was noticeable in the fields where treatments were discontinued too soon or where an insufficient number of applications were made with too long intervals between them. Fields receiving the proper number of applications at the right intervals were adequately protected, and practically no pods were lost.

Direct comparison of the effectiveness of the different numbers of applications was difficult because such factors as time of planting, time of first and last dusting, and intervals between applications varied in different fields.

However, by assembling and grouping all the data from 22 treated Mexican chili pepper fields, these differences were leveled out, and a definite trend was indicated, showing that as the number of dustings increased better control was obtained (Table 2).

Table 2.—Effect of various numbers of cryolite applications on production of pods of Mexican chili peppers.

Number of Applications	Number of Fields	Average Number of Pods per Plant		
		Highest-Producing Field	Lowest-Producing Field	All Fields
0	11	7.8	0.04	3.6±0.8
2 to 3	4	13.3	1.2	8.9±2.8
5	11	19.2	4.8	11.6±1.2
6 to 9	7	21.6	9.9	17.2±1.5

A further interesting comparison can be made in that the treated field with the lowest number of pods, 1.2 per plant, received only 2 applications, while the field with the highest number of pods, 21.6 per plant, received 9 applications. Both of these fields were late, and planted on the same day, May 10.

TIME OF PLANTING.—Since all fields were planted late this year, it was impossible to determine the full effect of time of planting on total production. Ordinarily, the earlier the fields are planted, the less damage the pepper weevil does.

Two untreated adjoining fields were observed at Santa Marguerita. One, planted about the middle of April, produced 3.7 pods per plant, and the other, planted about the middle of May, produced 0.04 pod per plant.

In another case the effect of time of planting on pepper weevil damage was very striking. All of one 72-acre field of Mexican chili peppers was treated as a unit, receiving two applications, and was given the same cultural care, except that 55 acres were planted April 17 to 21 and 17 acres were planted May 10. The early part of the field produced 10.0 pods per plant, while the late part produced only 1.2 pods per plant. This low producton was due primarily to the fact that at the time of the greatest weevil infestation these young pods had not matured enough to be as resistant to attack as the older pods in the field planted earlier.

However, the effect of late planting can be overcome by continuing the applications beyond the regular schedule. This is illustrated by the field of Mexican chili peppers previously referred to, which was planted May 10. This was very late, but the owner treated it nine times, and it produced 21.6 pods per plant.

COST OF TREATMENT.—The cryolite-talc cube dust mixture cost $12 per hundred pounds. The cost per acre per application ranged from 25 cents for power dusting to 60 cents for hand dusting.

By the use of a range of quantities from 15 to 20 pounds per acre per application, a minimum and maximum cost per acre is easily estimated. It cost $10.25 per acre to apply cryolite five times with a power duster at the rate of 15 pounds per acre, or $11.25 for 20 pounds per acre. One

grower who used hand dusters made nine applications at an average rate of 20 pounds per acre, and his cost was $27 per acre. The actual cost of treating the chili pepper fields examined averaged $15.28 per acre.

It is estimated that a production of 15 pods per plant corresponds to approximately 1 ton per acre of dried Mexican chili peppers. As shown in table 1, the average increase as a result of the cryolite treatment was 10.2 pods per plant, or more than two-thirds ton per acre. At the present price of 15 cents per pound this gives a gross profit of $200 just for this increase per acre. After deduction of the cost of treatment, $15.28, and $5 per ton for washing, as well as $60 per ton for drying the increased tonnage, the net profit is $141.39 per acre on this increase in yield directly due to putting on the insecticide applications to control the pepper weevil.

The profits from treatment of California chili peppers and paprika were even greater than in the case of the Mexican chili, because control measures were more successful on these varieties, production was slightly greater, and the price was 5 cents per pound higher than for the Mexican chili pepper.

A careful estimate of the pepper fields of southern California showed that 2660 acres of Mexican chilies were dusted this year. As explained in a previous paragraph, the average net profit on the treated crop was $141 more per acre than on the untreated crop, making a total net profit of $375,060 to the growers of these 2660 acres of Mexican chilies. In addition, 910 acres of California chilies and paprika peppers were treated this year. At an average net profit of $208 per acre for the increased tonnage due to treatment, this makes a total net profit on the acreage of these varieties of $189,280. Therefore, pepper growers in southern California made a total net profit of $564,340 just on the added portion of their crop which was produced as a result of insecticide treatment.

CAUSES OF POOR RESULTS.—During these studies it was observed that there were very few infested peppers in some treated fields, while in others, even in those which had been treated several times, there were many infested pods, both on the ground and still on the plants. Further investigation showed that the cause of poor control in these fields could be laid to several things, such as making the first application too late, not continuing the applications long enough, too long an interval between applications, too light an application, and, in a few cases, the use of poor or careless methods.

One grower, in an attempt to avoid a poisonous residue on his peppers, made four applications of a commerical pyrethrum dust. His best field averaged 7.1 pods per plant, while nearby untreated fields averaged 4.2, 5.1, and 6.9. His two other pyrethrum-dusted fields averaged 2.7 and 4.8 pods per plant. There were no undusted fields adjoining these, but a cryolite-treated field near by averaged 9.9 pods per plant. These figures may also be compared with the average of all the fields examined, which was 4.7 pods per plant for untreated fields and 13.3 pods per plant for the cryolite-treated fields.

These results indicate little or no control from pyrethrum, which is in accordance with previous experimental results and field observations.

SUMMARY.—The season of 1941 was an excellent one in which to analyze results of pepper weevil control obtained by growers in southern California. A cryolite-tale-cube dust mixture was used at the rate of 15 to 25 pounds per acre per application, applied with power and hand dusters.

The following program was recommended: Three dustings at 5-day intervals, starting when the first pods begin to set, a 10-day interval with no dustings, and then three more dustings at 5-day intervals. This program was followed by many growers.

Growers installed adequate washing equipment so that poisonous residue was successfully removed.

The average number of pods per plant was used in comparing treated with untreated fields. Two hundred plants per field were examined, and 46 fields were included in this survey.

The treated fields produced more than 3 times as many pods as the untreated fields.

Fields dusted 6 to 9 times produced more pods than those dusted 2 to 5 times.

Late-planted fields were more severely damaged by the pepper weevil than fields planted earlier.

The average net profit on treated fields was $141 to $241 more per acre than on untreated fields. It was estimated that 3570 acres of peppers were treated, bringing the total net profit to $594,370.

Poor results were obtained by some growers, owing to applications which were too light, or which were put on at the wrong time.

The use of pyrethrum dust in three fields showed little or no evidence of control.

Even under conditions of a heavy infestation, excellent control of the pepper weevil was obtained by growers who used a 50 per cent cryolite dust containing rotenone and applied it carefully at prescribed intervals and quantities.—1-6-42.

A Method for Rearing Citrus Thrips in the Laboratory

FRANCIS MUNGER, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

In the field the eggs of the citrus thrips, *Scirtothrips citri* (Moult.), are laid in succulent plant tissue. The larvae of this species feed largely on the upper surface of tender citrus leaves until full grown, when almost invariably they drop from the tree to pupate. There are several generations during the warm season, when the thrips population may show wide fluctuations. During the cold months active stages may be present, but the insect is mostly in the egg stage.

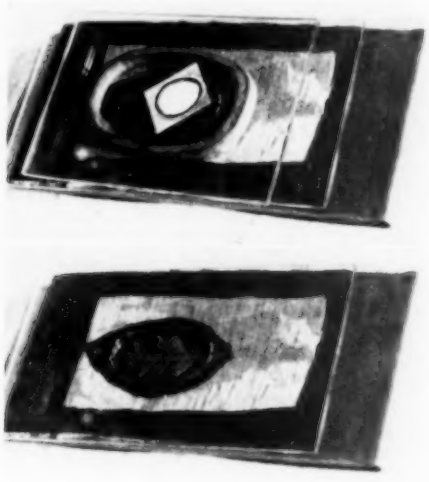

FIG. 1.—(Lower) The leaf is kept alive by holding it in contact with a moist pad. (Upper) The plaster cage with ventilated cover is set over the leaf to confine either adult or immature thrips.

Because of the lack of a continuous supply of thrips in the field, the difficulties of collecting large numbers at any time, and the need for material of known age, a method of rearing thrips in the laboratory for toxicological tests has been developed.

For rearing thrips it is necessary to have a cage that is gas permeable and without crevices or pockets into which the larvae might go to pupate. To facilitate the making of observations it should be transparent from above. Provision must also be made for suitable plant tissue for feeding and egg laying. In the case of the latter, the same plant tissue must be kept in healthy condition throughout the incubation period of the egg, which at 77° F. ranges from approximately 7 to 35 days. These requirements have been met by the use of a cage consisting of two sheets of glass in which oval holes have been cut, separated by an oval ring of plaster. The upper surface of a citrus leaf is sealed against the opening in one of the sheets of glass and the other surface is placed in contact with a moist pad.

Detached citrus leaves with the petioles removed can be kept alive for sufficient time by holding the under side of the leaf in contact with the moist pad. A lemon leaf about $1\frac{5}{8}$ by $3\frac{1}{2}$ inches, cut from an actively growing twig, is suitable both for food and for an egg depository for the thrips. The leaf is kept moist, and at the same time the upper surface is made available to the thrips by sealing the leaf with paraffin to the rim of a hole in a piece of glass and then laying the plate and the back of the leaf against the pad (Fig. 1). The paraffin is applied with a brush at a temperature of 108° F. The insects are more easily seen against the paraffin if lampblack is added to it.

The pad (Fig. 2) consists of a piece of plywood, a piece of thick cloth the same size as the wood, and a 4-inch section of automobile inner tube. One layer of the wood in the middle of the board is cut out to allow room for the leaf and to prevent crushing the midrib. In assembling the

preparation the thick cloth is laid over the depression in the wood, the rubber stretched over the board, and the wet cheesecloth placed on the rubber.

The glass best suited for the work is 4-by-8-inch, nonwavy, double-strength window glass. The exact size and shape of the hole to be made is first outlined with a glass cutter. The scratch is then cracked through the glass from the opposite side.

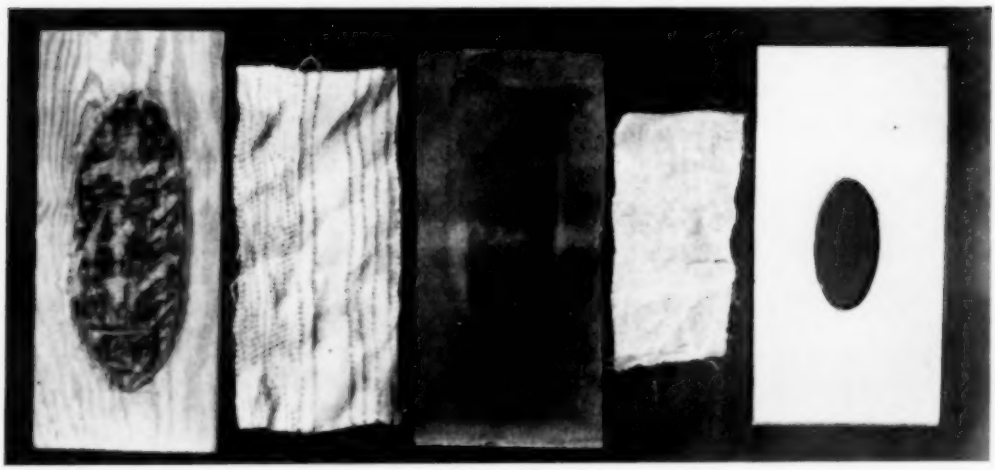

FIG. 2.—The pad consists of plywood, thick cloth, rubber, cheesecloth, and perforated glass.

Several parallel longitudinal scratches are then made on one side within the outline, and similar cross scratches are made on the other side. These scratches are all cracked through. Finally the glass is laid on a smooth piece of wet iron, and the portion of the glass to be removed is pulverized by striking it repeatedly with the hammer end of the cutter. After a hole has once been started, the rest of the glass is gradually removed with a notch of the glass cutter. The sharp edges are then polished off with a carborundum stone.

The oval-shaped ring is made of a dental plaster known as artificial stone. The plaster is cast in a form composed of two metal strips clamped between two pieces of plate glass. The inside dimensions of the cage are $2\frac{1}{8}$ by $3\frac{1}{2}$ inches. The height is three-eighths inch. Before the plaster is poured, it is placed under a vacuum for a few minutes to remove air bubbles, and during the pouring the form is vibrated violently to prevent air pockets from forming. The setting of the plaster can be delayed by adding a few drops of ammonia to the water. After the cast is dry, it is soaked in ink to give it a dark color. The finished ring is set on the glass in such a position as to surround the exposed portion of the leaf. A glass plate provided with a hole covered with bolting cloth having a count of 150 threads to the inch is used as a cover (Fig. 1). This assembly is used both for ovipositing and for later rearing of the larvae.

Leaves are exposed to the reproducing insects to obtain the eggs. These leaves are then covered and held until the larvae have hatched. During incubation the plaster ring is not used, but the glass cover is placed directly on the glass plate, with the bolting cloth uppermost, and above the leaf to allow transpired moisture to escape. When a fairly large number of larvae have hatched (50 to 100 or more), they are brushed en masse into a rearing cage containing a leaf dusted with sugar. It is desirable to allow the larvae to feed for a number of hours on the leaf from which they hatched before transferring them to fresh food, because fewer casualties result with the larger larvae. Also, since the insects are to be grown to the adult stage in this cage without additional food, more insects can be reared per cage if they are partially grown before they are transferred.

An outstanding characteristic of the adult citrus thrips is its rapidity of movement, particularly when stimulated mechanically. This agility of the insect, com-

bined with its small size, has made necessary the use of an anesthetic (chloroform) in order that it may be handled in the laboratory. When the thrips in the cage have reached the adult stage, they are quieted with chloroform and the cage is placed over a new leaf onto which the insects are brushed. On this leaf the insects are allowed to feed and oviposit. A little powdered sugar or magnesium carbonate worked into the brush will help prevent the insects from adhering to the bristles. The chloroform is administered by means of a staining jar cover and a small wad of cotton. The cotton wad, of a size to hold about one drop of the anesthetic, is placed on the concave side of the glass cover. The cover is then inverted over the bolting cloth of the cage and left there for about a minute. Care should be exercised not to administer more than enough chloroform to quiet the insects. A hundred adult insects in a cage require a fresh leaf about every 24 hours. As many as several hundred thrips may be handled in one cage, but they must be transferred to fresh food more frequently, since leaves which have been fed upon too long do not keep well. Supplementary food, however, can be added to advantage in the form of sugar sprinkled over the leaf (Munger 1941). In the laboratory a constant temperature of 87.5° F., with a relative humidity of 50 per cent, is a favorable condition for the rearing. At this temperature approximately 5 days are required for the insects to progress from the hatching of the egg to the adult stage. Apparently the thrips can be bred indefinitely in the laboratory, since 22 generations were reared consecutively without loss of vigor or other ill effect.

For studying pupal development or transferring the insects in the pupal stage, the following technique is useful: Full-grown larvae are strongly thigmotactic and wander about the cage looking for a suitable crevice in which to pupate. In the rearing cage they usually locate in one of the angles where the plaster and the glass meet. A lure is made of two cover glasses and de Khotinsky cement. One glass is superimposed on the other with a fragment of a cover glass between them in such a way as to form an interstice. The glasses should nearly touch at one side and be separated by 0.4 mm. on the other. The lure is laid flat on the glass plate near the leaf. The larvae will congregate in the area where the glasses are separated by about 0.2 mm. (Fig. 3), and nearly all the insects will be caught.

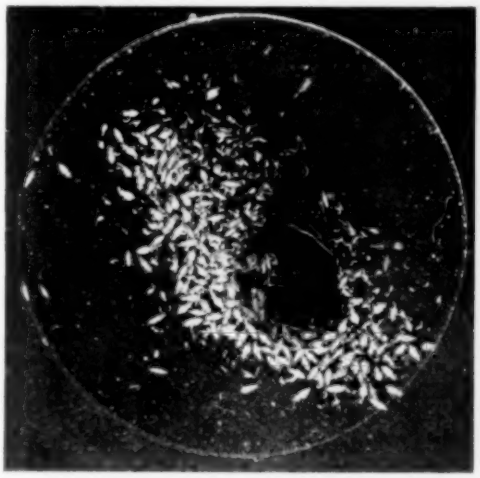

FIG. 3.—Full-grown larvae in the rearing cage can be trapped in the narrow crevice of a lure composed of two cover-glasses.

A beginning stock of thrips larvae may be collected in the field by means of a screened box (McGregor 1926). Infested twigs in the orchard are beaten against the screen, and the insects are caught alive on a clean, removable, black plate. Usually from 50 to 75 larvae are transferred from the plate to the cage, but fewer larvae should be reared at one time if they are very recently hatched, because of the limited food supply, even when sugar is present.—1-6-42.

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Calcium Cyanamid, a Possible Practical Control for Pear Thrips, in Prune Orchards

E. P. Breakey, *Western Washington Experiment Station, Puyallup, Washington*

The control of the pear thrips, *Taeniothrips inconsequens* (Uzel) in the prune orchards of Clark County, Washington, has become one of the major problems confronting the industry. Statements in the literature indicate that the situation in Clark County is similar in many respects to that prevailing in other sections where the insect is a pest. About the only weapon available to the grower in his efforts to control this insect has been the use of contact insecticides. That satisfactory control from the use of contact insecticides is neither general nor consistent is well known. Moreover, control by cultural methods when the thrips are in the ground is limited in both application and effectiveness.

The discovery by Huber & Baur (1939) that the development of the apothecia of the brown rot fungus, *Sclerotinia fructicola* (Wint.) could be prevented by the timely application of pulverized and oiled (5 per cent oil) calcium cyanamid of commercial grade to the surface of the soil and vegetative cover under prune trees suggested that the effect of this material on emerging thrips should be investigated.

Experimental Methods and Results.—Studies in the prune orchards of Clark County in the spring of 1939 (Huber *et al.* 1939) showed that pulverized and oiled calcium cyanamid of commercial grade, when applied to the soil at the rate of 300 pounds per acre, reduced the number of overwintering thrips to emerge from the soil by approximately 90 per cent. Duplicate areas were treated in orchards in three localities within the period of March 3 to 27. The average total number of thrips to emerge as determined by trap counts on non-treated areas in the three orchards was 708.5, 133.5, and 48.5, respectively, and on the treated plots was 79, 13.5, and 5.5, respectively. The pyramid-shaped traps used were designed after those described by Smith (1934), the principal difference being that each was covered with a tightly woven waterproofed canvas. Each trap covered 9 square feet. These studies also showed that the time to apply the dust for maximum effectiveness was shortly before the overwintering thrips began to issue from the soil.

These studies were continued in the spring of 1940 (Breakey *et al.* 1941). Several acres were treated in each of three orchards, using a power duster (Baur & Huber 1941), to broadcast the calcium cyanamid at the rate of 300 pounds per acre. The duster was equipped with a hood and short apron to confine the calcium cyanamid near the ground, and to prevent it from drifting into the trees. Two of the orchards were located in Fruit Valley and the third on upland with a southwest exposure toward Lake Vancouver. The period was one of almost daily rainfall, the dust at times being applied in the rain, a condition contrasting with that which prevailed in 1939, a season of comparative dryness and with little or no interference from rainfall.

Table 1.—Control of pear thrips in prune orchards with calcium cyanamid—1940.

Pounds per Acre	Trap No.	Total Thrips pet Trap	Total Thrips per Treatment	Per Cent Thrips Reduction
		Valley Orchard No. 1		
300	8	3		
300	16	1	4	89.19
Check	1	16		
Check	20	21	37	00.00
		Valley Orchard No. 2		
300	14	32		
300	23	1	33	94.99
200	41	10		
200	42	23	33	94.99
100	39	12		
100	40	4	16	97.57
Check	5	295		
Check	13	363	658	00.00
		Upland Orchard		
300	18	269		
300	24	264	533	83.59
200	31	50		
200	32	16	66	97.97
100	29	58		
100	30	416	474	85.41
Check	11	2270		
Check	22	977	3247	00.00

Some insight into the effectiveness of lighter applications of the dust was gained from tests on small trial plots where the calcium cyanamid was applied with a hand duster at the rates of 200 and 100 pounds per acre, respectively. Each plot included an area 20 feet square with a tree at its center, the trees in the orchards being set at distances of 20 feet each way. All tests were made in duplicate. The data obtained have been summarized in table 1.

Table 2.—Materials and rates of application.

TREATMENT	MATERIAL	APPLICATION PER ACRE (LBS.)
1	$CaCN_2$	single–100
2	$CaCN_2$	single–200
3	$CaCN_2$	single–300
4	$CaCN_2$	split–100&200
5	$CaCN_2$	split–150&150
6	$CaCN_2$	split–200&100
7	$CaCN_2$+superphosphate	100+216
8	$CaCN_2$+superphosphate	200+216
9	$CaCN_2$+superphosphate	300+216
10	$CaCN_2$+hydrated lime	200+50
11	$CaCN_2$+hydrated lime	200+100
12	$CaCN_2$+hydrated lime	200+200
13	checks	

The results obtained from the use of calcium cyanamid in 1940 confirmed those obtained in 1939. Moreover, the lighter applications were apparently equally effective in the control of the pear thrips. There are several reasons for interest in the possible use of the lighter applications. As noted above, the use of calcium cyanamid in this manner has been shown to be destructive to the apothecia of the brown rot fungus, and is an accepted source of nitrogen in meeting fertilizer requirements. Moreover, it appears that two applications of the calcium cyanamid dust may be indicated where the control of both pests is sought, as an application timed for the control of the pear thrips is, under certain weather conditions, too early for maximum effectiveness against the brown rot fungus. In such a situation the ligher applications would doubtless be preferable from the standpoint of economy and might also be indicated by the fertilizer requirements of the crop.

The results of these exploratory studies seemed to justify more extensive investigations into the possible application of calcium cyanamid to the problems noted. Such investigations were set up with the following objectives in mind: 1, To check the results obtained in previous years; 2, to determine the effectiveness of split applications of calcium cyanamid; and 3, to determine the effect of the application of either superphosphate or hydrated lime on the toxic principle of calcium cyanamid. The schedule of materials and rates of applications are set forth in table 2.

Each treatment was replicated four times, and each replication included an

Table 3.—Control of pear thrips in prune orchards—1941. A. W. Moody orchard, Felida, Wn.

TREATMENT	TRAP NO.	THRIPS PER TRAP	THRIPS PER TREATMENT	THRIPS REDUCTION (PER CENT)
15 None	1	534		
	2	522		
	3	927		
	4	429	2412	
$CaCN_2$ 100 lbs.	16	95		
	18	100		
	29	14		
	48	25	234	90.33
$CaCN_2$ 200 lbs.	11	94		
	22	5		
	37	86		
	43	103	288	88.11
$CaCN_2$ 300 lbs.	24	75		
	26	57		
	32	40		
	53	44	216	91.05
$CaCN_2$ 100 & 200 lbs.	7	42		
	36	63		
	42	58		
	60	58	221	90.84
$CaCN_2$ 150 & 150 lbs.	10	55		
	12	102		
	15	38		
	46	16	211	91.22
$CaCN_2$ 200 & 100 lbs.	39	53		
	47	97		
	51	30		
	56	79	259	89.27
$CaCN_2$ 100 lbs. plus Superphosphate 216 lbs.	6	55		
	27	59		
	30	147		
	31	144	405	83.21
$CaCN_2$ 200 lbs. plus Superphosphate 216 lbs.	17	208		
	41	141		
	49	135		
	55	156	640	73.89
$CaCN_2$ 300 lbs. plus Superphosphate 216 lbs.	13	161		
	19	155		
	25	98		
	35	91	505	79.07
$CaCN_2$ 200 lbs. plus Hydrated lime 50 lbs.	21	38		
	34	92		
	54	126		
	57	153	409	83.05
$CaCN_2$ 200 lbs. plus Hydrated lime 100 lbs.	20	84		
	28	4		
	33	108		
	58	275	471	80.49
$CaCN_2$ 200 lbs. plus Hydrated lime 200 lbs.	8	36		
	9	24		
	40	100		
	59	232	392	83.75

area 20 feet square with a tree at its center, the trees in the orchard being set at a distance of 20 feet each way. The dust for each application was weighed out separately and applied with a small power duster. Initial applications were timed for (Fig. 2). Reference to figure 2 shows that the emergence of the insect got under way early in March in 1941. Initial applications of the dusts in 1941 were made on March 7, the second portions of the split applications being applied ten days later.

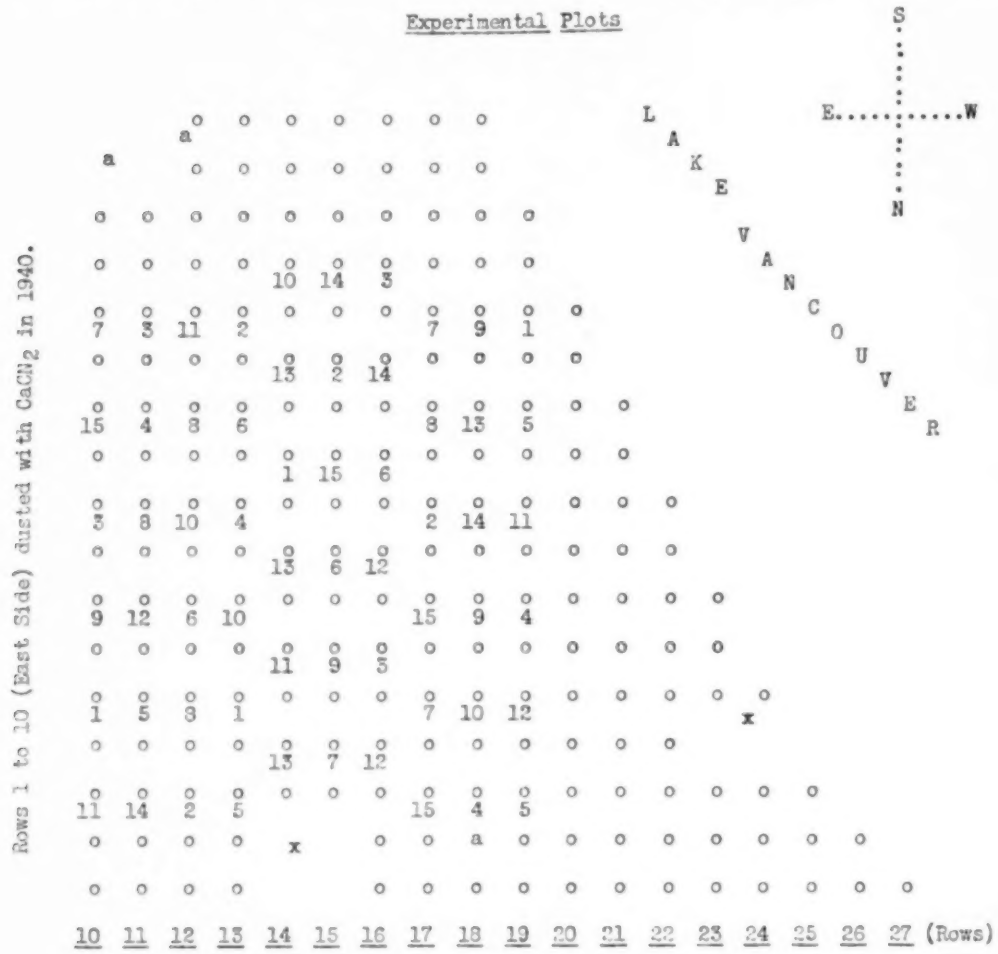
Experimental Plots
S
E
W
N
LAKE VANCOUVER
Rows 1 to 10 (East Side) dusted with $CaCl_2$ in 1940.
10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 (Rows)

FIG. 1.—Control of pear thrips in the A. W. Moody Orchard—1941 (x = cherry; o = prune; a = apple). Numerals indicate treatment numbers.

maximum effectiveness against the thrips, the second portion of the split applications being timed for maximum effectiveness against the brown rot fungus.

The experimental plots were staked out in the A. W. Moody orchard in the Felida district according to the plan shown in figure 1. Data available on the emergence of the thrips in the Felida district indicate that the dates for the initial emergence of the insect in 1939 and 1940 had not been as accurately determined as desirable

Thrips were collected and counted daily. Duplicate sets of *Vial traps* were prepared and numbered to correspond to the trap numbers, one set to be in operation while the thrips in the other were being counted. As the *Vial traps* containing thrips were removed they were immediately placed in a large cyanide jar of sufficient size to accommodate an entire set.

The results obtained from the studies

made in 1941 have been summarized in table 3.

The lighter applications again proved to be as effective as the heavier. Moreover, subsequent applications apparently failed to increase the effectiveness of the treatment. The addition of the superphosphate reduced the effectiveness of the calcium cyanamid as did also the lime.

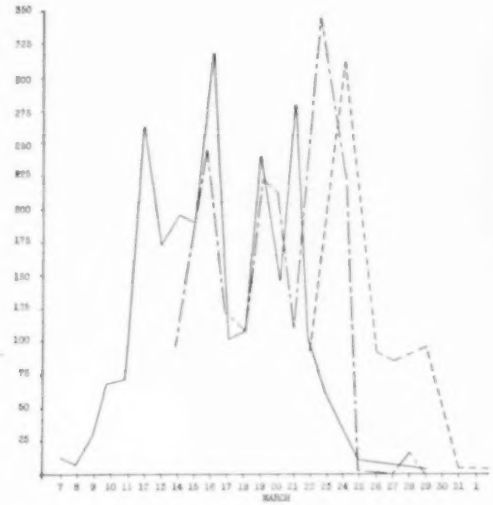

FIG. 2.—Pear thrips emergence in the A. W. Moody Orchard. (Solid line, 1941; long and short dashes, 1940; short dashes, 1939).

In addition to the experimental work just outlined, the Washington Growers' Association dusted about 300 acres of prunes for grower members. The application of the calcium cyanamid dust was made possible through the purchase of a tractor and power duster (Fig. 3). The dust was applied in two applications at the rate of 150 pounds per acre for each application. The initial application was timed for maximum effectiveness against the pear thrips, the second application being made approximately ten days later in order to prevent the development of the apothecia of the brown rot fungus.

Material on which to base blossom counts was collected in several of these orchards. These collections were made as the emergence period of the thrips was drawing to a close. Blossoms were picked at random near the centers of the treated areas and placed immediately in bottles containing alcohol as a preservative. Corresponding collections were made in neighboring orchards which had not bene dusted. These collections were later assayed for thrips in the laboratory with the aid of a binocular microscope. The results are presented in table 4. These data indicate that the results obtained from large-

FIG. 3.—Power duster adapted to application of calcium cyanamid.

scale applications of the calcium cyanamid dust are in line with those obtained experimentally. It will be noted that the thrips population in Orchard No. 8 was high. This orchard was near the Hainsley orchard and was used as a check on the control obtained there. Both were in an area of heavy infestation well removed from the orchard in which the experimental plots were laid out.

Table 4.—Control of pear thrips in prune orchards—1941. Blossom counts—Clark County.

LOCATION OF ORCHARD	TREATMENT	NO. BLOSSOMS	NO. THRIPS	PER CENT BLOSSOMS WITH THRIPS
Leonard's	Dusted	109	14	12.8
W. of Leonard's	No dust	100	41	41.0
Rathbone's	Dusted	105	2	1.9
N.E. of Rathbone's	No dust	103	43	41.7
Firestone's	Dusted	244	3	1.2
S. of Firestone's (C. L. Wooley)	No dust	222	47	21.1
Hainsley's	Dusted	171	25	14.6
N.E. of Hainsley's	No dust	190	184	96.8
Miles' (East Orchard)	Dusted	148	5	3.3
Miles' (West orchard)	No dust	276	28	10.1

DISCUSSION.—The timely application of pulverized and oiled (5 per cent oil) calcium cyanamid of commercial grade to the surface of the soil in prune orchards, at the rate of 300 pounds per acre or less, reduced the number of overwintering thrips to emerge from the soil by approxi-

mately 90 per cent. The toxicity of calcium cyanamid, or its decomposition products, to such organisms as seeds and certain fungi has been studied by several investigators. Crowther & Richardson (1932) suggest that either the cyanamid itself, or its acid salt is responsible for the toxic action. They found that high temperature, low soil moisture, and thorough application of the dust is definitely beneficial.

Since the emergence of the thrips continues over a period of several weeks it is desirable that the period of toxicity be extended over as much of this period as possible. The temperatures encountered and the normally high moisture content of the soil, together with the method of application of the material, tended to produce an extended period of toxicity. Since soil temperature data were not obtained, maximum and minimum air temperatures for the period of this study are given (Fig. 4). Smith (1929) has discussed the lag of soil temperatures behind those of the air. The average temperatures encountered during the progress of these studies were below the lowest used by Crowther & Richardson (56° F.), with the possible exception of a few days at the close of the period in 1941. Moreover, the

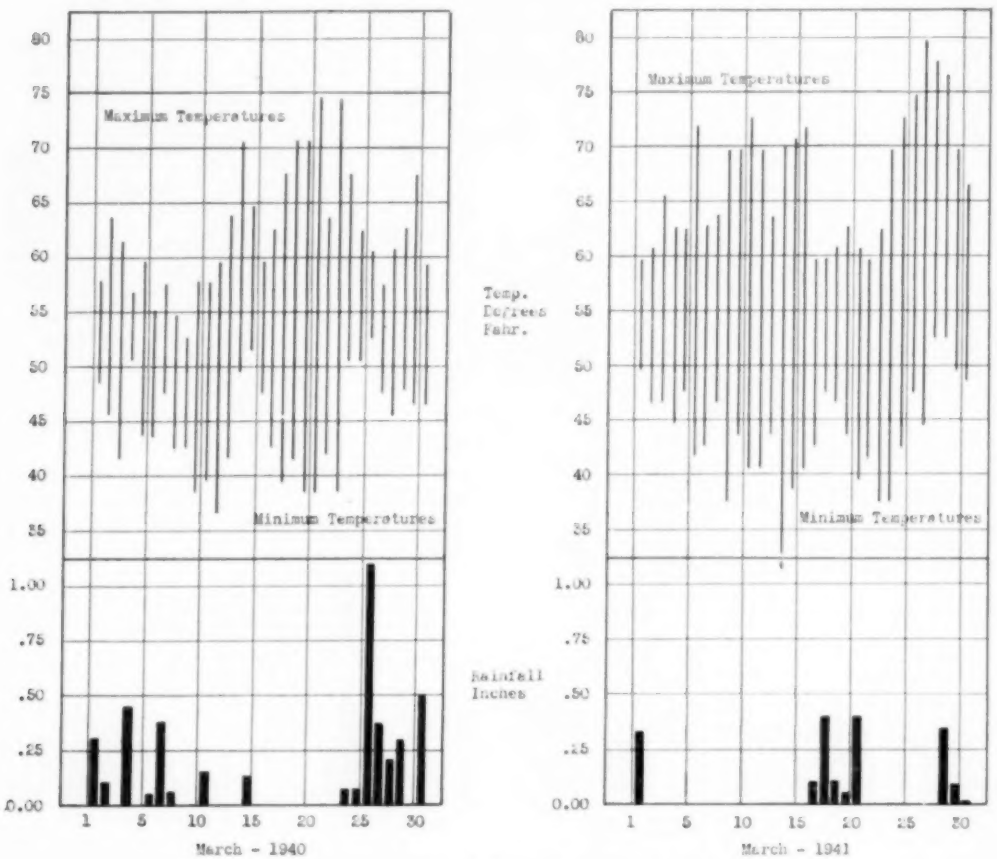

FIG. 4.—Temperature and rainfall records in pear thrips experiments.

incorporation of the material with the soil shortened the period of toxicity, while low temperatures, higher soil moisture and surface concentration of the cyanamid slowed the process of decomposition and increased the period of toxicity.

While not prepared to demonstrate the application of this principle to thrips control, the writer is of the opinion that it offers an explanation for certain irregularities which showed in the day to day catch of thrips. To be specific, a rain following within a day or two of the ap-

normal field moisture capacity of the soil was apparently greater than any used in their studies (Fig. 4). Incorporation of the material in the soil was avoided by applying it as a dust to the surface of the soil and vegetative cover.

The utilization of the nitrogen in the calcium cyanamid dust must also be considered in an orchard-management program. Crowther & Richardson (1932) have shown that nearly all soils contain the necessary catalysts for the conversion of the nitrogen of calcium cyanamid to urea. The soil encountered in these studies is identified as Felida silt loam and consists of 42.5 per cent silt, 24.5 per cent clay and 33 per cent sand, has a pH of 5.9 and contains a moderately high reserve of more or less readily soluble iron. According to Crowther & Richardson, calcium cyanamid is hydrolized to urea in slightly acid media and the reaction is catalyzed by many inorganic compounds, including certain zeolites, and especially the salts or oxides of iron or manganese, which are found for the most part in the finer soil separates. It appears, therefore, that soil conditions were favorable for the utilization of the nitrogen in the calcium cyanamid.

The effect of the calcium cyanamid on the cover crops should also be mentioned. The vegetative cover of the valley orchards consisted of a mixture of Austrian field peas and chickweed, *Stellaria media* (L.) Cyrill., while the Moody orchard had been planted to vetch. Within a few days, following the application of the dust, the vegetative covers had taken on a badly burned appearance and the odor of decomposition was noticeable. However, in most instances, new growth appeared within two or three weeks and the vegetative cover seemed to come back with increased vigor. This was especially true of the vetch.

Of interest also, is a comparison of the temperatures in a trap with those in the open tree above the trap. Data for making this comparison are recorded in table 5. It will be noted that the greatest differences occurred when the day was clear and bright and with no wind. Even then the maximum difference between the two temperatures was only about 10 degrees.

Table 5.—Control of pear thrips in prune orchards. A. W. Moody orchard, Felida, Wn. Comparison of temperatures in trap with those in tree above trap.

Date	Time	Temp., Degrees F. In Tree	In Trap	Weather
March 27 1940	10 A.M.	48	50	Rain
	11 A.M.	48	50	Rain and wind
	12 M.	50	50	Wind—cloudy
	1 P.M.	50	49	Rain
	2 P.M.	52	48	Wind-broken sky
	3 P.M.	54	52	Sun through clouds
	4 P.M.	53	55	Cloudy
	5 P.M.	55	49	Rain
March 11 1941	11 A.M.	68	74	Clear bright windy
	12 M.	70	75	Clear bright windy
	1 P.M.	70	76	Clear bright windy
	2 P.M.	72	79	Clear bright windy
	3 P.M.	72	80	Clear bright windy
	4 P.M.	68	76	Clear bright windy
March 12 1941	9 A.M.	50	60	Clear bright no wind
	10 A.M.	58	68	Clear bright no wind
	11 A.M.	69	75	Clear bright no wind

SUMMARY.—The timely application of pulverized and oiled calcium cyanamid (5 per cent oil) of commercial grade to the surface of the soil in prune orchards at the rate of 300 pounds per acre or less, reduced the number of overwintering thrips to emerge from the soil by approximately 90 per cent.

The use of calcium cyanamid in this manner is also known to prevent the development of the apothecia of the brown rot fungus. Since two applications of the calcium cyanamid dust may be indicated where the control of both pests is sought the effect of the split application on the emergence of the thrips was investigated. Apparently dividing the application does not add to its effectiveness as a control for the thrips.

Since calcium cyanamid is an accepted source of nitrogen in meeting fertilizer requirements and its use in combination with other soil amendments might be indicated, the effect of the addition of certain of these materials on its toxic properties was investigated. Both superphosphate and hydrated lime materially reduced the toxicity of the calcium cyanamid.

Large scale applications of calcium cyanamid dust were made in the prune orchards of Clark County, approximately 300 acres having been dusted in the spring of 1941. The dust was applied in two applications of 150 pounds each, the initial application being timed for maximum effectiveness against the thrips, the second application being made approximately 10 days later in order to prevent the develop-

ment of the apothecia of the brown rot fungus. Blossom counts made over treated and untreated areas at the close of the emergence period of the thrips indicate results in keeping with those obtained experimentally.

Grower interest, stimulated by favorable results, suggests that the use of calcium cyanamid in this manner may become standard orchard practice.—1-19-42.

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The Grape or Vine Thrips, *Drepanothrips reuteri*

STANLEY F. BAILEY, *University of California, Davis*

Since the grape thrips was first reported from North America in 1926 there have been two periods of severe injury noted, namely, 1927–28 and 1936–37. Whether *Drepanothrips reuteri* Uzel will continue to increase its range and severity of attacks as other injurious thrips have done or become a proven vector of plant disease, it is impossible to say. Nevertheless, at present it is considered as a species of minor economic importance (Moulton 1931; Bailey 1938) and such information as has accumulated on its biology should be recorded.

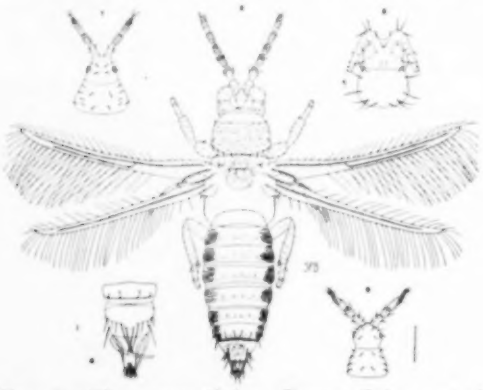

FIG. 1.—The grape thrips, *Drepanothrips reuteri* Uzel.
1. Head and pronotum of mature larva.
2. Adult female.
3. Head and pronotum of pupa.
4. Terminal abdominal segments of male.
5. Head and pronotum of first instar larva.

Line at left of 4 equals 0.01 mm.; that at right of 5 equals 0.1 mm. which is also the magnification of 1, 2, and 3.

ECONOMIC IMPORTANCE.—This thrips is of very minor importance when compared with such pests of grape vines as the grape leafhopper, the red spider and even the locally sporadic grape leaf-folder. However, in years when the price of table grapes is unusually good, the scarring of the fruit by *Drepanothrips reuteri* Uzel becomes of some moment. This injury takes the form of a russetting or checking of the skin of the berry (Fig. 2). In badly infested vineyards it is common to find 50 per cent of the bunches showing scars, with many clusters having all the berries scarred (Fig. 3) as is the case some years on the second set of fruit. The actual damage, resulting from feeding or the chafing of the mouthparts is done early in the season, usually up to the time the fruit is about one-third grown. Both adults and larvae feed on the berries but the larvae are responsible for most of the injury since they generally feed in small

colonies. During the summer practically no feeding is done on the berries; the feeding stages concentrate on the tender canes and unfolding leaves.

In seasons of severe damage the young canes of midsummer are killed and all the new leaves put out on the periphery of the vines after late June are curled and present a scorched appearance (Fig. 3). In such cases, the growth of young vines is somewhat stunted and their vitality reduced. The injury, in seasons of light infestations is spotted, both by districts and in individual vineyards. Some injury of this type is to be seen every year in addition to varying degrees of scarring on the berries. However, if the grapes are used for juice purposes such damage is of little concern unless the scarring prevents normal development.

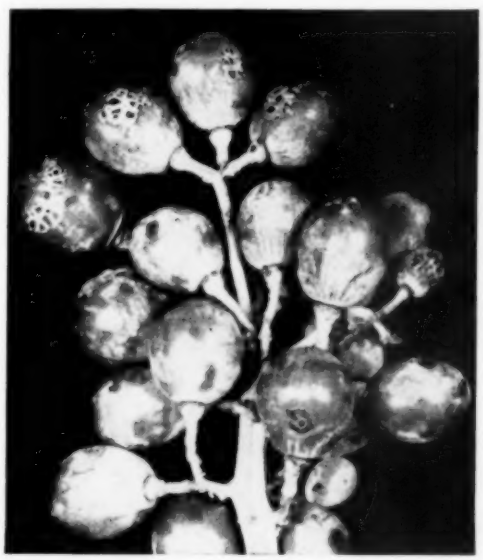

FIG. 2.—Russetting and checking of table grapes by *Drepanothrips reuteri* Uzel is very noticeable on the berries at maturity as is shown above.

BIOLOGY.—Until recently the life history of this insect was not known. Only a few scattered facts of a biological nature have been previously recorded. Uzel (1895) described it from specimens collected from leaves of oak, beech and hazelnut in Bohemia. Pantanelli (1911) wrote that *D. reuteri* passed through two principal generations in Sicily; the first on the basal buds in April and May and a second on the young shoots and suckers in August

FIG. 3.—Russetting and stunting of juice grapes by *Drepanothrips reuteri* in May renders them unfit for use.

and September. Stscherbakov (1913), Fulmek & Karny (1915), and Fedorov (1938) stated that the female hibernates under bark and in the ground. Previous collection records during the growing season range from April to September.

The life history and seasonal cycle of this thrips has been worked out at Davis, Lodi, and in Fresno County, chiefly near Sanger. Rearing methods employing cellophane cages and individual cells described elsewhere were used. The type of life

FIG. 4.—Stunted canes and curled leaves of grape caused by *Drepanothrips reuteri* in midsummer as is evidence by the shortened internodes and dwarfed leaves.

history exhibited by *Drepanothrips reuteri* is in general typical of the members of its group. A summary of the length of the various stages, worked out under summer conditions at Davis is given in table 1.

Table 1.—Summary of life history stages of grape thrips in midsummer.

Stage	No. of Individuals	Range (Days)	Average (Days)
Egg	48	6–10	7.2
Larva (first and second instars)	68	4–9	6.6
Prepupa	101	1–1.5	1.0
Pupa	99	1.5–5	2.1
Preoviposition period		3–6	5.0
Total life cycle			21.9
Number of generations annually			5–6

While it is possible for a maximum of six complete generations to occur, actually there is considerable overlapping of broods and a seasonal peak of the population is normally reached about the last week in July. The adults emerge from hibernation in small numbers at the time the buds open in late March. At this season only females have been found which indicates that the first brood is reproduced asexually as is commonly the case with the onion thrips, bean thrips, and western flower thrips. By midsummer the sex ratio is about eight females to one male. In October the males disappear and the last adults seen are females. Bud counts made in 1941 indicate the trend of emergence: March 11, 110 buds showed three adults; March 20 in 50 buds six adults were found; and on March 28, 26 adults, many of which were gravid, were collected from 75 buds. These forms live 10 to 20 days and the larva begin to hatch in early April from eggs inserted in the leaf and stem surfaces. During this period the canes grow so rapidly that the larvae are scattered and are found chiefly on the basal leaves. By the first of May adults begin to appear in numbers and are most commonly collected on the upper surface of the small leaves. During June and July all stages are found and, as the growth of the vines slows down, the thrips population becomes concentrated on the newly developing leaves. In August, as the vines begin to mature the infestation gradually slackens. The population rapidly declines through September and October. Only in very exceptional cases, where basal shoots still have tender leaves present are any grape thrips found after about October 10th. In the fall of 1938 a few adults only were present on unfrosted leaves as late as November 19.

The pupae are difficult to find in the field (as are the citrus thrips) but by diligent searching they are located in moist, curled leaves under the vines and in the moist top soil. In the laboratory they seek out curled leaves, depressions in the bark and crawl downward among clods. When disturbed they are extremely active. No cell or cocoon is made. Black cloths and pyramid-shaped, tarpaper-covered traps were used in collecting the maturing larvae which drop from the vines and the newly emerging adults.

It has been mentioned above that in Russia and Sicily adults were found hibernating under the bark of the vines. For the past 4 years the writer has searched most carefully under the bark in the field and used a modified Berlese funnel in the laboratory for obtaining all possible hibernating forms. Dead adults only have been found under the bark. Other species of thrips, namely *Frankliniella moultoni* Hood, *Anaphothrips zeae* Moulton, *Thrips tabaci* Lind., *Limothrips angulicornis* (Jablon.), *Hercothrips fasciatus* (Perg.), and *Leptothrips mali* (Fitch) have all been found hibernating under the bark of grape vines. Emergence traps such as are employed for pear thrips have been placed under the vines in the spring and only isolated adults caught. A careful search among fallen leaves and the soil itself in the winter has not revealed the presence of any pupae (as is the case in *Rhipiphorothrips cruentatus* Hood a pest of grapes in India reported by Rahman & Bhardwaj, 1937). No winter host plants are known. Therefore, the conclusion is reached that, in California, this thrips spends the winter in the soil, chiefly as the adult, surviving only in very small numbers. Infestations are much greater in sandy soil than heavy loam or adobe types of soil. Also, during dry seasons when irrigating begins early spring infestations are greater. In northern Europe on the native hosts (Hukkinen & Syrjanen, 1937) only a few specimens have been collected while in southern Russia and Sicily it becomes sufficiently abundant to be injurious. Pantanelli (1911), however, stated that the injury to

the vines was more severe in damp places.

In general the appearance and activity of the adult are similar to the citrus thrips. The adults run about very rapidly, especially on warm days. Both species are amber yellow in color and very small. They fly readily and are easily dispersed by a slight breeze. The relative abundance of various species of thrips from a random collection on white table grapes is shown by the following data gathered at Davis on July 24, 1939, from the foliage:

Species	*Number of individuals*
Drepanothrips reuteri Uzel	75
Frankliniella occidentalis (Perg.)	11
Leptothrips mali (Fitch)	8
Anaphothrips zeae Moulton	5
Thrips tabaci Lind.	2
Aeolothrips fasciatus (L.)	2
Scolothrips sexmaculatus (Perg.)	1
Hercothrips fasciatus (Perg.)	1

TAXONOMIC POSITION.—*Drepanothrips reuteri* is a member of the family Thripidae and subfamily Sericothripinae. The genus is readily told from its relatives by the 6-segmented antennae and the two longitudinal veins in the fore wings. *Drepanothrips viticola* Mokr., described in 1901, and *Thrips betulicola* Reuter, (1899) are the only synonyms (Fulmek & Karny 1915, Priesner 1930, 1933). There are no other species in the genus. Its closest relative is probably the citrus thrips, *Scirtothrips citri* (Moulton) for which it is sometimes mistaken.

HOSTS.—The host plant list of *Drepanothrips reuteri* is not large. In Europe it is recorded from maple, birch buds, beating grass, beech, hazelnut, grape, willow and oak. In California it has been collected from grape and poison oak, *Rhus diversiloba*, only. Among grape varieties this thrips shows a great preference for the white varieties such as Thompson Seedless, Malaga, Sultana and Moliniere. It has been collected also from Palomino, Tokay, Alicante, Carignane, Zinfandel, Petite Sirah, Mission, Black Prince, Pinot, St. George and Sauvignon Vert.

DISTRIBUTION.—In North America this thrips has a very limited distribution, being at present known only from California. Saunders (1890), however, reported that in Washington, D. C., "for several years the foreign grapes under glass have been severely injured by thrips." The species concerned apparently was not determined. In California it has been, since its discovery (Moulton 1926) most abundant in the central San Joaquin Valley grape growing districts. Its distribution by counties is now known to be as follows: Kern, Tulare, Fresno, Madera, Merced, Stanislaus, San Joaquin, Sacramento, Yolo, Butte, Santa Clara, Solano, Napa, Sonoma, and Mendocino.

The grape, or vine thrips as it is more commonly known in Europe, is very widely distributed. It is listed from Austria, Bohemia, Denmark, England, Finland, France, Hungary, Italy (and Sicily), Roumania, Russia (Latvia, Crimea and the Caucasus).

OTHER SPECIES OF THRIPS ON GRAPES.—Other species of thrips have been found on cultivated grapes in California. Of these, *Aeolothrips fasciatus* (L.), *Franklinothrips vespiformis* Crawford, *Scolothrips sexmaculatus* (Perg.), and *Leptothrips mali* (Fitch) are predaceous. In wild grape flowers a species of *Heterothrips* is commonly seen in the spring only. *Limothrips angulicornis* (Jablon.), *Anaphothrips zeae* Moulton, *Hercothrips fasciatus* (Perg.), *Sericothrips variabilis* (Beach), *Scirtothrips citri* (Moulton), *Frankliniella occidentalis* (Perg.) (including *moultoni* Hood), *F. minuta* Moulton, and *Thrips tabaci* (Lind.) are commonly seen on the foliage and young berries as well as in the flowers.

Abroad, other species of thrips are known to be injurious to grape vines. Bagnall (1915) and Solomides (1916) record *Cryptothrips brevicollis* Bagn., as injurious in Cyprus. Serious injury to vines in Italy is discussed by del Guercio (1918) and Zanon (1917) and attributed to *Dictyothrips aegyptiacus* (Marshal). Rahman & Bhardwaj (1937) published an extensive report on the injurious grape-vine thrips, *Rhipiphorothrips cruentatus* Hood of India.

DESCRIPTION OF STAGES.—Reference has been made above to the original description. Other authors, namely, Pantanelli (1911), Fulmek & Karny (1915), Moulton (1928, 1931) and Bailey (1938) have given brief descriptions, chiefly of the adult. Bagnall (1922) redescribed and illustrated the male. Priesner (1926) has given a complete description of the adult, larva, and pupa. Detailed descriptions of the various stages do not appropriately find a place here.

The female is about 0.75 mm. in length,

amber to orange in color with patches of brown pigment on pronotum, meta- and meso-notum as well as a brown band across the dorsum of abdominal segments 2–7 on the anterior margin. The three basal antennal segments are light yellow to light brown and with the three terminal segments dark brown to black. The ocelli are crimson and the eyes black. The fore wings are uniform gray-brown and the hind wing without color.

The male is smaller, more slender, and much lighter in color with two black, sickle-shaped claspers projecting, one from each side, at the tip of the abdomen.

The mature larva is about the same size as the adult and is yellow or amber in color, somewhat flattened, with short antennae and a bluntly pointed abdomen. The eyes are red and the body is covered with evenly spaced, blunt bristles which are expanded at the tip.

The non-feeding stages, the prepupa and pupa, are pale yellow or translucent and typically thripoid in appearance.

CONTROL.—So far, it has been unnecessary for growers to practice specific control measures for *D. reuteri* since the contact sprays and dusts of oil, pyrethrum, and nicotine used for the grape leafhopper considerably reduce the thrips population (Moulton 1928, Jacobson 1927, 1928). A spray composed of two pounds of tartar emetic and four pounds of sugar per 100 gallons of water gives a remarkable kill of adults and larvae. When necessary, such a spray applied in May or June will prevent further injury to young shoots and berry clusters.—1-26-42.

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Efficiency of Nicotine Sprays for Codling Moth Control in the Pacific Northwest

F. P. Dean, E. J. Newcomer, C. C. Cassil, and C. C. Alexander, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

Following the development of a tank-mix nicotine bentonite by Steiner & Sazama (1938), Steiner *et al.* (1938), and others for the control of the codling moth, this nicotine combination was tested at Yakima, Wash., under the arid conditions of the Pacific Northwest. This was done primarily in an effort to find an effective spray that would not leave an objectionable residue on the fruit. Some preliminary tests had been made with several other nicotine sprays in 1936 and 1937 with rather promising results, but in 1938 the formula suggested by the above-mentioned workers was used, and the tests have been continued for 3 years.

Methods.—Field tests were made in three apple orchards each year. The varieties were as follows: Orchard A, Delicious; orchard B, Rome; and orchard C, Jonathan in 1938 and Winesap in 1939 and 1940. The infestation was relatively light in the Delicious orchard, heavy in the Rome and Jonathan orchards, and fairly heavy in the Winesap orchard. The experimental block in each orchard was divided into quarters, and each of 8 or 10 spray treatments was replicated on small randomized plots of three trees in each quarter. Thus every treatment included 36 trees each season. The size of the crop was uniform within orchards for each year, and it was apparently not influenced by the treatments. The variations in crop that did occur from tree to tree did not appear to influence the results. The spraying was done with a stationary power sprayer at a pressure of about 350 pounds per square inch. The dates of application are shown in table 1.

Each year at harvest 250 apples taken at random from the entire crop, including drops, were gathered from each tree and examined for worm injury. After the data were classified according to the number of worms and injuries per 100 apples they were statistically analyzed, in order that tests of significance between treatment means might be made.

Table 1.—Dates of application of nicotine and other sprays.

Application	1938	1939	1940
		First brood	
Calyx	May 6–11	Apr. 27–May 3	Apr. 26–May 3
First cover	May 20–25	May 8–13	May 13–18
Second cover	May 31–June 4	May 17–23	May 23–29
Third cover	June 9–16	May 26–June 1	June 3–11
Fourth cover	June 21–27	June 5–13	June 13–22
		Second brood	
Fifth cover	July 11–19	June 26–July 11	July 8–15
Sixth cover	July 25–29[1]	July 17–Aug. 1	July 23–Aug. 3
Seventh cover	Aug. 6–11	Aug. 7[2]	Aug. 13–20[1]
Eighth cover	—	Aug. 21–22[2]	—

[1] Not applied in orchard A.
[2] Applied only in orchard B.

During 1940 careful observations were made on the infestation at intervals during the season. This was done by tagging 500 apples chosen at random around the lower parts of the trees in treatments 1 and 3, and recording the infestation on these apples at weekly intervals. This was started in July, shortly after the last application of nicotine bentonite, the two later applications consisting of nicotine sulfate and miscible oil.

As a part of the study chemical analyses of spray deposits were made in 1940 on representative samples, taken immediately before and after each of the seven cover sprays and at the time of harvest. In general, the method of sampling was like that used by Fahey & Rusk (1939) in Vincennes, Ind., and may be described briefly as follows: Seven apples from the top, ten from the middle, and eight from

the bottom section of each of two adjacent trees were collected by clipping the stems and allowing them to fall into a tared glass container, two 25-apple samples being obtained from each plot sampled. Certain variance studies conducted at this station during the 1940 season have confirmed the adequacy of this sampling technic with respect to "within-tree" variance. Three plots in the Winesap orchard, one plot in the Rome orchard, and one plot in the Delicious orchard were used for deposit determinations.

Measured quantities of sodium hydroxide solution (0.5 per cent in the case of nicotine deposits and 6.0 per cent in the case of lead arsenate deposits) were added to the jar in which the apples were collected and placed in a shaking machine which turned it end over end at the rate of about 65 r.p.m. In this way the residue was removed not only by the solvent action of the alkali but also by the mechanical action of the apples rubbing against one another as they rolled from one end of the jar to the other. After a 5-minute shaking period, the solvent was poured from the apples and a portion used for the chemical determination. The colorimetric method described by Markwood (1939) was used for the analyses of nicotine. This method employs beta naphthylamine and cyanogen bromide for the development of a red-colored solution with nicotine, and the color was measured in a photoelectric photometer. The arsenic analyses were made by the method described by Cassil & Wichmann (1939).

COMBINATIONS TESTED.—The tank-mix nicotine bentonite was prepared as follows: For each 100 gallons of water in the spray tank, 1 pint of nicotine sulfate (40 per cent nicotine) was added, and, with the agitator running, 5 pounds of Wyoming bentonite was poured in slowly, followed by 1 quart of soybean oil. Sodium lauryl sulfate, at the rate of 0.5 ounce to 100 gallons, was used in some of the tests, and this was put into the water first. This combination of nicotine bentonite is designated "standard tank mix" in this paper. Following the suggestions of Steiner *et al.* (1938), the quantities of nicotine sulfate and bentonite were reduced to 0.67 pint and 3 pounds, respectively, in the sprays for the second brood, and the final applications of the season consisted of 0.67 pint of nicotine sulfate and 1 gallon of home-made mineral-oil emulsion or 3 quarts of miscible oil. This was done to prevent objectionable residues of bentonite at harvest. The oil was also used with nicotine sulfate throughout the season in one test in 1939, and alternately with the bentonite and soybean oil in 1939 and 1940, for comparative purposes.

The home-made oil emulsion contained 75 per cent of a lubricating-type oil having a Saybolt viscosity at 100° F. of 60–65 seconds, and the miscible oil was a commercial product containing 97 per cent of oil classed as light-medium, with a viscosity of 65 seconds.

In order to obtain a measure of the efficacy of the nicotine bentonite, lead arsenate at 3 pounds to 100 gallons, with various stickers or wetting agents, was used in comparison with it. These accessory materials included a fish-oil-soap spreader at 1 pint to 100 gallons, an oil spreader at 1 pint to 100 gallons, tar soap at 0.25 pound to 100 gallons, and a commercial miscible oil at 3 quarts to 100 gallons. The inverted spray mixture known as W.S.C. dynamite spray (Marshall & Groves 1938) was also used.

For the calyx spray 2 pounds of lead arsenate to 100 gallons, without any accessory material, was used in all treatments discussed in this paper.

WEATHER.[1]—Rainfall in the arid Yakima Valley is light, the normal annual precipitation being 6.78 inches. For the months of May to September, inclusive, the approximate period during which protection from worm attack is needed, normal rainfall is 2.22 inches. The actual rainfall for these months during the years covered by this work was less than normal, being lowest in 1939 and highest in 1940, and it did not greatly exceed the normal in any individual month.

Temperatures were similar during the three seasons, and there is no evidence that activity of the codling moth or deposit of insecticides was influenced by either temperature or rainfall.

RESULTS.—The data obtained on codling moth injury in the plots receiving the various treatments during the three seasons are summarized in tables 2, 3, and 4. The treatment numbers originally used

[1] All weather data are taken from the annual and monthly meteorological summaries of the U. S. Weather Bureau Station at Yakima.

Table 2.—Comparative efficiency of lead arsenate and nicotine sprays in controlling the codling moth, Yakima, Wash., 1938.

Treatment No.	Treatment (Quantity per 100 Gallons)	Orchard A		Orchard B		Orchard C	
		Number per 100 Apples		Number per 100 Apples		Number per 100 Apples	
		Worms	Injuries	Worms	Injuries	Worms	Injuries
1	Lead arsenate 3 lb. and fish-oil-soap spreader 1 pint	2.3	10.0	14.8	68.7	71.8	199.5
2	Lead arsenate 3 lb. and W. S. C. dynamite	0.6	4.2	3.0	16.0	16.2	75.1
5	Nicotine bentonite, standard tank mix (oil emulsion substituted for bentonite and soybean oil in last application)	3.4	6.5	15.4	24.1	48.1	78.1
	Differences required for significance (19 to 1)	0.9	5.2	14.3	53.1	27.6	80.5

in the orchards are retained in these tables.

Treatments other than nicotine and lead arsenate included in the same series of experiments are omitted from the paper since they are of no interest in this connection. The results of the chemical analyses made in 1940 are shown graphically in figures 1 and 2. The infestation records made at intervals from July 18 to September 12 are shown in figure 3.

DISCUSSION.—In evaluation of the results it should be borne in mind that the number of worms per 100 apples is a more important criterion than the total number of injuries, which often consist largely of stings. Many more stings resulted from the use of lead arsenate than from the use of nicotine. Stings, however, unless there are more than four or five per apple, do not reduce the value of the fruit more than

Table 3.—Comparative efficiency of lead arsenate and nicotine sprays in controlling the codling moth, Yakima, Wash., 1939.

Treatment No.	Treatment (Quantity per 100 Gallons)	Orchard A		Orchard B		Orchard C	
		Number per 100 Apples		Number per 100 Apples		Number per 100 Apples	
		Worms	Injuries	Worms	Injuries	Worms	Injuries
1	Lead arsenate 3 lb. and oil spreader 1 pint	6.4	29.3	23.6	85.6	15.5	93.5
2	Nicotine bentonite, standard tank mix (oil emulsion as in treatment 6 substituted for bentonite and soybean oil in last application in orchards A and C and in last two applitions in orchard B)	17.4	25.3	52.6	82.7	35.9	60.2
5	Nicotine sulfate and oil emulsion as in treatment 6, second, third, fifth, and sixth cover sprays; nicotine bentonite as in treatment 2, other sprays	13.7	21.6	58.6	97.3	46.0	83.4
6	Nicotine sulfate 1 pint, first-brood sprays; 2/3 pint, second-brood sprays; oil emulsion 1 gal., all sprays	19.8	32.0	80.3	156.4	74.7	115.1
	Differences required for significance (19 to 1)	6.6	15.3	35.1	58.7	41.8	56.7

Table 4.—Comparative efficiency of lead arsenate and nicotine sprays in controlling the codling moth, Yakima, Wash., 1940.

Treatment No.	Treatment (Quantity per 100 Gallons)	Orchard A		Orchard B		Orchard C	
		Number per 100 Apples		Number per 100 Apples		Number per 100 Apples	
		Worms	Injuries	Worms	Injuries	Worms	Injuries
1	Lead arsenate 3 lb., all sprays; miscible oil 3 qt., second, third, and fifth cover sprays; tar soap 1/4 lb. other sprays	6.9	36.7	60.1	207.8	16.3	96.0
3	Nicotine bentonite, standard tank mix (miscible oil substituted for bentonite and soybean oil in last two applications)	13.3	22.9	84.1	139.4	36.0	84.4
4	Nicotine bentonite as in treatment 3 with addition of 1/2 oz. sodium lauryl sulfate	16.9	27.8	98.4	154.6	50.8	100.6
5	Nicotine sulfate 1 pint, miscible oil 3 qt., second, third, and last two applications; nicotine bentonite as in treatment 4, other sprays	21.9	37.6	82.7	140.7	42.1	92.8
	Differences required for significance (19 to 1)	3.5	7.2	24.7	53.2	21.0	40.5

about 25 cents per box, under the grading rules in force in the Pacific Northwest, but worm holes may practically destroy the market value, which may be considerably more than 25 cents per box.

On this basis the results obtained with nicotine bentonite in 1938 appeared favorable. Following treatment with this material there were no more worms and fewer stings than occurred following the lead arsenate treatment. In 1939, however, this apparent efficiency was not duplicated. Also, the substitution of oil emulsion for the bentonite and soybean oil in four applications, in an attempt to reduce the quantity of visible bentonite on the fruit, was made without impairing the efficiency of the schedule. It is probable that the

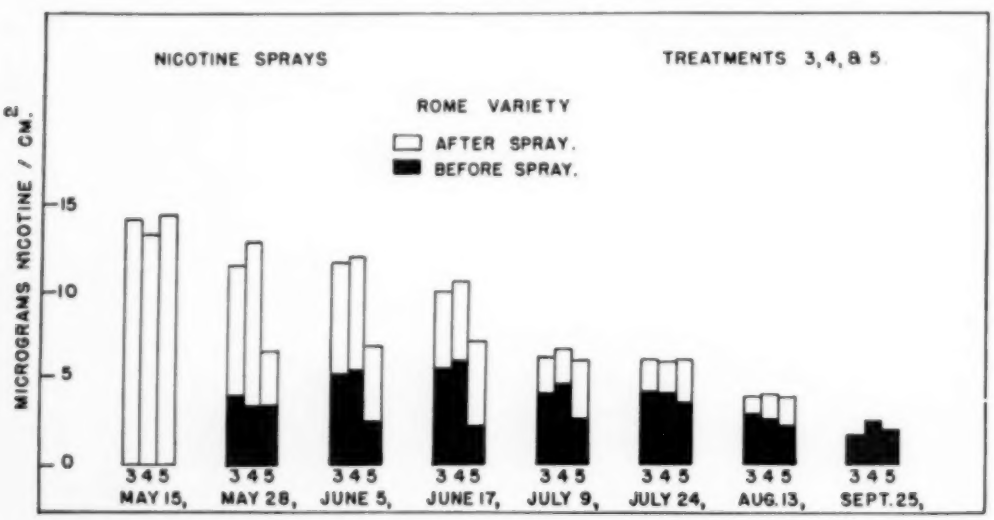

Fig. 1.—Deposit of nicotine maintained on Rome apples, 1940.

action of the oil in killing eggs more or less offset the reduction in deposit of nicotine resulting from the omission of the bentonite. Examples of such reduction are shown in figures 1 and 2. The substitution of oil emulsion for the bentonite and soybean oil throughout the season, however, materially reduced the efficiency of the treatment.

Because of the poor results obtained in 1939, more detailed studies were made in 1940. The extensive chemical analyses made during that season showed that (1) the use of sodium lauryl sulfate did not influence the quantity of deposit in the standard tank-mix; (2) nicotine bentonite deposited considerably more nicotine residue than a nicotine-oil spray; and (3) the nicotine deposits dropped abruptly when a reduced concentration of nicotine with oil was applied toward the latter part of the season, and this was probably the reason for the reduced codling-moth control during the second brood at the height of infestation. Nicotine deposits on the Delicious variety were comparable to those shown for the Winesap and Rome varieties, but are not given because the results were not complete for the first-brood sprays. The control blocks of trees sprayed with lead arsenate carried an average deposit of about 23 mmg. of arsenic trioxide per sq. cm. after spraying and 12 mmg. before spraying.

A limited number of analyses[1] made during 1938 and 1939 show the same general trend both with lead arsenate and nicotine as those results obtained in 1940.

The periodic observations on infestation made in 1940 (Fig. 3) showed that up to about 10 days after the first application of nicotine-oil (sixth cover spray) there were fewer worms in the apples sprayed with nicotine than in those sprayed with lead arsenate. Following this, however, the nicotine-sprayed fruit became wormy much more rapidly than the fruit sprayed with lead arsenate.

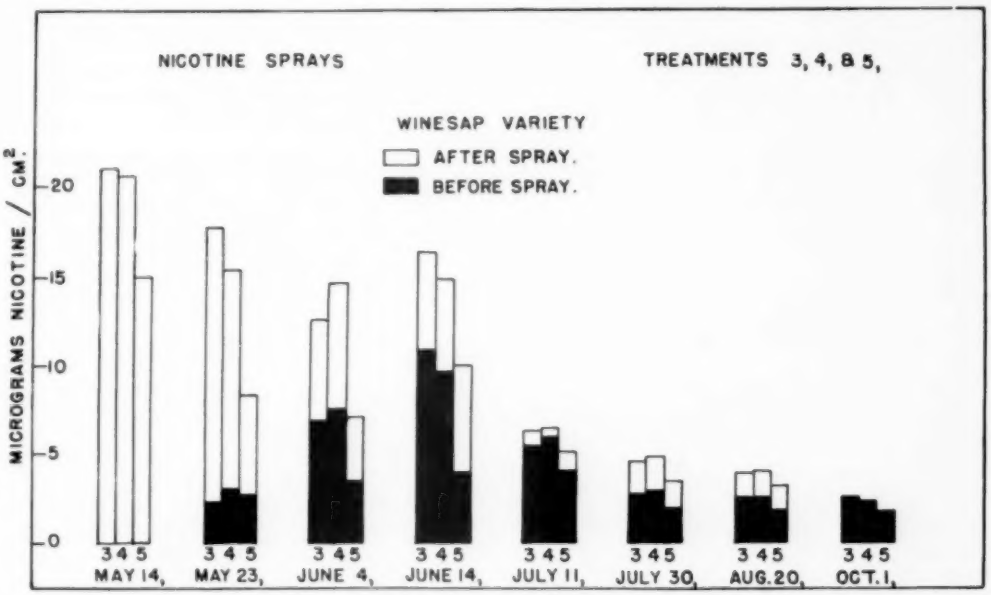

FIG. 2.—Deposit of nicotine maintained on Winesap apples, 1940.

It is evident that the frequent applications of the standard tank-mix nicotine bentonite made up to July constituted a treatment at least equal to the usual schedule of lead arsenate. It is evident also that the reduction in the quantity of nicotine and the substitution of mineral oil for bentonite and soybean oil in the later sprays, as well as the longer interval between these sprays, resulted in insufficient protection of the fruit, and this is reflected in the chemical analyses (Figs. 1 and 2).

Steiner (1940) has pointed out the

[1] Analyses for 1938 and 1939 were made by C. W. Murray and J. F. Cassidy, formerly of this Bureau.

danger of drawing conclusions from small replicated plots because of the fact that there is a constant levelling-off of population owing to the migration of moths from tree to tree. It is therefore pertinent to look at the possible effect such migration might have on these results.

In 1938 the nicotine treatment did not leave more worms per 100 apples than did the lead arsenate, although there were two

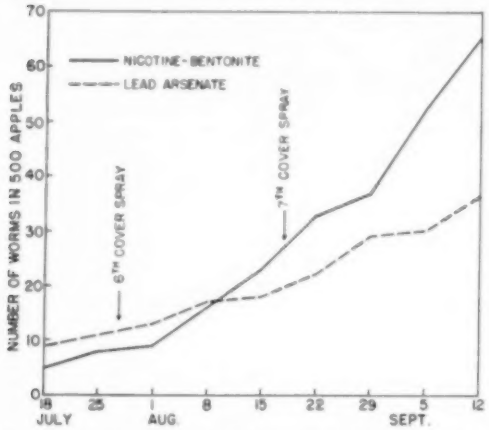

FIG. 3.—Infestation of apples sprayed with nicotine bentonite and lead arsenate, 1940.

other treatments in the experimental block that were much wormier. This may have been due to the somewhat shorter season and to the use of bentonite about 10 days later than in 1939 and 1940. There is no evidence that differences in rainfall or temperature caused it.

In 1939 most of the treatments were of nicotine bentonite and in no other treatments was the population of worms any greater than in these. All of orchard A, consisting of about 250 trees, was rather isolated from other apple trees and therefore free from outside infestation. More than half the trees were sprayed with nicotine, and preliminary examinations, made July 1, indicated that there were fewer worms in the trees sprayed with lead arsenate than in those sprayed with nicotine. Thus any levelling-off of population that might occur would be in the direction of decreasing the population in the nicotine-sprayed trees and increasing it in the trees sprayed with lead arsenate. There could be little argument here that the greater infestation in the nicotine-sprayed trees at harvest was due to migration of moths from trees sprayed with lead arsenate. It was apparently due to the lower efficiency of the nicotine treatments during the latter part of the season.

In 1940 several other treatments were used which resulted in many more worms per hundred apples than the nicotine treatments, and this increase occurred gradually throughout the season. Thus there should be a constant migration of moths to the nicotine-sprayed plots. And yet there was no greater difference in the results with nicotine and with lead arsenate than in 1939.

CONCLUSIONS.—The tests included in this paper do not indicate that the standard tank-mix nicotine bentonite would be a satisfactory substitute for lead arsenate in the Pacific Northwest. However, sufficient tests have not been made on a large scale to determine whether this material would work the same way under such conditions. Until such tests can be made, no suggestion for the use of nicotine for controlling the codling moth in the Pacific Northwest can be offered, except that it might be used in lightly infested areas, particularly in pear orchards.—1-19-42.

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Experiments for Controlling the Western Peach Borer

A. E. Michelbacher and Ray F. Smith, *University of California, Berkeley*

Further requests for work on the control of the western peach borer was made by farmers in San Benito County, California. They felt that in many cases paradichlorobenzene was not giving the desired control and since ethylene dichloride had been reported as giving good results in the south and east, they felt that this fumigant should be tested under California conditions. Mr. Roy McCallum, farm advisor of San Benito County, made arrangements for the experiments.

A survey of the orchards in the vicinity of Hollister was made and it was found that in most places the borers were being effectively held in check and that there were only a few orchards where the borer infestation was sufficiently large to be suitable for experimental work. Even in heavily infested orchards uninfested trees could be found.

Historical Summary.—The Western peach borer, *Sanninoidea opalescens* (Hy. Edw.) is closely related to the eastern species *S. exitiosa* Say, which worked over to peach from native hosts when commercial peaches were introduced into the eastern states and became one of the most serious pests of this crop. Like its eastern relative, the western peach borer attacked commercial plantings in those areas in the west where conditions were favorable for its development and it became a serious pest of apricot, prunes and peaches.

The control measures tried against the western peach borer were the same as those that had previously been used in the east. Of all these, worming in the fall and spring proved to be the best. True enough, western investigators tried control measures such as carbon disulfide treatment (Woodworth 1902) but none of these proved satisfactory. Chemical control remained unsolved until Blakeslee (1919) published on paradichlorobenzene as a suitable fumigant for the control of *Conopia exitiosa*. Following this discovery paradichlorobenzene came into wide use and many eastern and middle western investigators recommend its use. For control of the western species, it has been recommended by Guyton & Stear (1925), Essig (1926), Newcomer (1941), and Mote (1935). For successful control it was found that the crystals had to be applied early in the fall when the soil temperature was sufficiently high to volatilize the fumigant. It was also found that care should be used to avoid letting the crystals come in contact with the bark for otherwise there was some danger of incurring injury. To secure good control it was necessary to mound the trees and for large trees a dosage of from 0.75 to 2 ounces was necessary to produce a good kill. Against borers on smaller trees lower amounts should be used, and on very young trees it cannot be recommended without a great deal of caution because of serious injury that may result. Where paradichlorobenzene was applied under proper conditions exceptionally good control could be expected. After the soil had warmed up sufficiently in the spring, it could also be applied, but the kill obtained was not as good as that to be expected from fall treatment.

Snapp (1938) found that ethylene dichloride was very effective against the peach borer. Later work (1939, 1941a) substantiated his previous work, and he again recommended this material. For treating large trees 0.5 pint of a 20 or 25 per cent emulsion was used and against borers in smaller trees a less concentrated emulsion was sufficient to give good control. Kills as high as 100 per cent were obtained. On two year old trees a 7.5 to 15 per cent emulsion applied at a dosage of 0.25 pint gave a 100 per cent kill, and nearly as good kill was obtained on one year old trees and nursery stock with a 7.5 to 10 per cent emulsion applied at the rate of 0.125 pint per tree. The use of ethylene dichloride has several advantages over paradichlorobenzene and among the important ones are that it can be used with safety on nursery stock and young trees and that it can be used at a time of the year when soil temperatures are so low that paradichlorobenzene would be ineffective. However, for best control it is necessary to mound the trees in the same manner as where paradichlorobenzene is used. Snapp in his work has pointed out

that there is some danger of applying ethylene dichloride to trees when high temperatures prevail, and that some slight injury is likely to occur where the soil is cracked.

Recently in the east some evidence has been obtained that would indicate that ethylene dichloride might cause some serious injury. In this regard Stearns (1941) makes the following statement:

"Unfortunately, in 1940, many peach trees died within the states from Virginia north, and ethylene dichloride emulsion may have been a contributing factor. Investigations have just been commenced by the Departments of Entomology at the Delaware, Pennsylvania, Virginia, and West Virginia Experiment Stations, and by the United States Department of Agriculture to determine whether or not the insecticide is effective, and can be used with safety under conditions in Delaware. Until the limitations of ethylene dichloride emulsion have been determined, it is not recommended as an optional treatment in this state."

Snapp (1941b) also commented on this situation, and believed much of the damage was due to winter-killing, although some evidently resulted where ethylene dichloride was used in excessive amounts or where recommendations were not followed.

INSECTICIDES USED.—The principal material investigated was ethylene dichloride. A stock emulsion was made by mixing four quarts of ethylene dichloride with five quarts of water to which four ounces of *Tergitol Emulsifier No. 7* had been added. To this stock emulsion, nine quarts of water were added to give a 25 per cent emulsion by weight.

A small amount of work was done with dichlorethy ether. This material was mixed with water to give a 25 per cent emulsion by weight. *Amine 220 E* was used as the emulsifier. Two per cent by volume of this agent based upon the volume of dichlorethy ether was added and completely dissolved in the dichlorethyl-ether before the water was added.

To serve as a comparison for late summer treatment paradichlorobenzene was used in two orchards.

CONTROL EXPERIMENTS.—Control experiments were started on February 9, 1940, and the last experimental series was set up March 27, 1941. Experimental plots were established at all seasons of the year except early and midsummer.

The 25 per cent ethylene dichloride emulsion was applied at the rate of one-half and three-quarter pint to the tree, although to a few trees a larger amount was applied to determine how much the trees could tolerate.

In all cases the emulsion was measured and the quantity poured on the soil about the base of the trunk in such a manner that some of it was poured onto the tree itself. Immediately after the application, the tree was mounded to confine the fumigant as much as possible.

Dichlorethy ether was applied in the same manner as ethylene dichloride emulsion, but in this case the amount applied never exceeded 0.75 pint to the tree.

In all cases paradichlorobenzene was applied in a circle about the base of the tree, and at a rate of two ounces of crystals per tree. Usually several months were allowed to elapse between the time of treatment and the time the trees were examined for borers. This period was generally of such a long duration that the borers killed by the treatment completely decomposed. Because of this the determination of the number of borers killed was rendered impossible. In order to approximate what the probable kill might have been, untreated trees in the same vicinity were examined and the difference in the number of borers found in the was taken as an index of control. Usually no fewer than 10 treated and 10 check trees were examined.

The selection of suitable experimental areas was rather difficult. Many factors had to be considered such as type of soil, root stock, size of trees, health of trees, and the evenness of infestation. This last factor was the most important. In all experimental orchards, a wide range in the infestation was observed. In one orchard the range in the check trees was 0 to 40, in another 0 to 15 and in the third 0 to 9. It was not uncommon to find an extremely lightly infested tree adjacent to a most heavily infested tree. Where borer control had been neglected, large portions of the cambium in some trees had been killed by attacks of previous years. In these trees it was not uncommon to find only an inch or two of living inner bark in which the borers might live. In such trees, only a single borer might be taken while a num-

ber would be taken in an adjacent tree which had more living inner bark. In one of the orchards, the available cambium per tree was probably the most important reason for the wide variation observed in the orchard. In this same orchard, it was observed that trees growing in the lighter soil type were more heavily infested than those growing in the heavier soil.

In making examinations for borers, the soil was first dug away from the tree, and then the borers were extracted with a borer tool. In extracting borers, they were often mashed, and where trees were examined at too short an interval after treatment, it was sometimes difficult to tell if the larvae were killed by the treatment or mashed in extracting them. It is for this reason several months were usually allowed to elapse between treatment and time of examination.

The size of the borers was observed at the time trees were examined. The development of borers under certain conditions is rather rapid for numerous individuals had attained the length of one inch in trees that were examined on December 4, 1940. However, in one orchard that was examined on May 20, 1941, a number of very small borers were observed. At the same time in other orchards, mature larvae were found, some had made their cocoons, and several had already pupated. The finding of very small larvae so late in the season may indicate that, at least in some cases, the larval period may last two years.

Sometimes borers are found well above the soil level. One was found on the trunk, 13 inches above the soil. Any borers that work their way well up the trunk of the tree are almost certain to escape the treatment.

During the winter and spring of 1940, the experimental work was confined to ethylene dichloride. The result of this work is summarized in table 1. In most of the work 0.5 pint of a 25 per cent emulsion was used, although 0.75 pint was applied in one case. The reduction under the check was in all cases rather good ranging from nearly 80 per cent to slightly more than 90 per cent. In spite of the small number of trees examined there were significant differences between the check trees and the treated trees in all cases except the treatment in the heavy soil. This was due to the greater variation in the low borer population in the heavy soil. There were no significant differences between any of the treatments. Differences probably exist between the dosages but because of the small number of trees used in each of the treatments they are not revealed. Apparently there are no differences between the February and May treatments.

During this period some work was done with individual trees to determine how much ethylene dichloride they could tolerate. One pint of the stock emulsion was

Table 1.—Control experiments against the western peach borer attacking medium-sized apricot trees with 25 per cent ethylene dichloride emulsion during winter and spring of 1940.

Date Treated	Soil Type	Amount Applied per Tree	Number of Trees Examined	Number of Borers Found per Tree ± S.E.	Control Expressed as Percentage
Feb. 9[1]	light sedimentary	check	10	2.1 ± 0.89	
		0.5 pint	10	0.2 ± 0.15	90.5
May 2[2]	heavy	check	10	1.9 ± 1.03	
		0.5 pint	10	0.4 ± 0.22	79.0
May 2[2]	light	check	20	3.2 ± 0.95	
		0.5 pint	20	0.3 ± 0.32	90.6
		0.75 pint	10	0.4 ± 0.40	87.5

[1] Examined—May 1, 1940.
[2] Examined—May 27, 1940.

applied to each of five old large trees. Some of these trees at least were not injured by this high concentration, and if any trees suffered from the treatment, the injury was slight. To another set of trees one pint of 25 per cent emulsion was added. This dosage caused no injury.

In the fall of 1940 some further work was done. On September 17, different plots were treated with 25 per cent emulsion of ethylene dichloride, 25 per cent emulsion of dichlorethylether and with paradichlorobenzene. Experiments were conducted in two orchards. More applications were made later during the fall, winter and spring, but in the later work only ethylene dichloride was used. The fall was very dry and the soil moisture was low until after the second experiment which took place on November 14. The results obtained in one of the orchards are shown in table 2.

Table 2.—Control experiments with ethylene dichloride and paradichlorobenzene against the western peach borer attacking very large apricot trees growing in a yolo silty clay loam.[1]

Date Treated 1940	Fumigant	Amount Applied per Tree	Number of Trees Examined	Average No. of Borers Found per Tree ± S.E.	Control Expressed as Percentage
	check		17	6.00 ± 2.03	
Sept. 17[2]	ethylene dichloride[3]	0.75 pint	19	2.10 ± 0.79	60.5
	Paradichlorbenzene[4]	2 ounces	12	0.17 ± 0.09	97.3
Nov. 14[2]	ethylene dichloride[3]	0.75 pint	11	5.18 ± 3.76	18.6[5]

[1] Average circumference of trees at base 43 inches; Age of trees about 45 years.
[2] Examined on Dec. 4, 1940.
[3] Twenty-five per cent emulsion by weight.
[4] Area probably not as heavily infested as portion of orchards treated with ethylene dichloride.
[5] There were 57 live borers collected and 13 dead borers, no check trees available for examination.

In the September treatment only those trees treated with paradichlorobenzene were significantly different from the checks. The control obtained gave a 97.3 per cent reduction under the check which was a reduction significantly different from the 60.5 per cent reduction obtained with ethylene dichloride applied on the same date. However, a subsequent examination of check trees showed that the paradichlorobenzene plot was in a slightly lighter infested area, despite the fact that an effort had been made to lay out the experiment so that all the plots contained trees that were nearly equally infested. In this orchard the trees were very large and 2 ounces of paradichlorobenzene or 0.75 pint of ethylene dichloride was applied to each tree.

Because of low temperatures ethylene dichloride was the only material experimented with on November 14. The kill obtained at this time was very poor, being less than 20 per cent. This was not significantly different from the trees treated in September. The reason for this poor showing is not completely understood. It is possible that the vapors given off from the ethylene dichloride escaped too readily from the very dry soil which was present in the orchard at the time of treatment.

In the second orchard, plots were treated on the dates mentioned above, and later on January 31, March 26 and March 27, 1941. On March 26 the ethylene dichloride was poured about the base of the trees without any preparation of soil. The soil had a hard thick crust due to the beating heavy winter rains. It was thought that this might influence the results so experiments were repeated on March 27 but this time the crust about the base of the trees was broken with a shovel. The results of the experimental work in this orchard during the fall, winter and spring are given in table 3.

In this orchard all the treatments were significantly different from the check trees whether they were compared to the nearest two checks or to a composite figure of all the check trees. When the treated trees were compared to the nearest check row

the differences were all significant except in the cases of the trees treated January 31 and March 26 with 0.5 pint of ethylene dichloride emulsion. This was no doubt due to the small number of trees in each of these checks; they being the smallest of the checks. None of the single check rows or the composite check, or the pairs of checks were significantly different from each other except in one case. The two checks involved here were at opposite extremes of the experimental area, and in one the number of trees examined was small and in the other sour sap influenced the results. They had the maximum and minimum mean check values of the experimental area.

The trees treated with paradichlorobenzene were not significantly different from any of the other treatments. The control was good giving a significant reduction of 81.8 per cent under the composite check.

A 25 per cent emulsion of dichlorethylether gave fair control when applied at the rate of 0.5 and 0.75 pints per tree. The 0.75 pint application gave the greatest reduction in borers but the difference from the 0.5 pint treatment was not significant. Moreover, the 0.75 pint dosage resulted in some tree injury. The treated trees lost their leaves earlier in the fall and the following spring the trees could be spotted by their lighter-green foliage. The control obtained with dichlorethylether was not significantly different from that of any other treatment.

Regardless of the time of treatment, whether it was September, November, January, or March the ethylene dichloride emulsion gave about the same degree of control. The differences between the treatments on various dates and dosages were never significant. The degree of control varied somewhat ranging from fair to good, and roughly averaged about 85 per

Table 3.—Results of experiments with several insecticides against the western peach borer attacking 24 year old apricot trees on myrobalan root stock.[1]

DATE TREATED[2]	FUMIGANT[3]	AMOUNT APPLIED	NUMBER OF TREES EXAMINED	AVERAGE NUMBER OF BORERS FOUND PER TREE ± S.E.	CONTROL EXPRESSED AS PERCENTAGE
Check	— —	— —	53	4.40 ± 0.61	
	ethylene dichloride	0.5 pint	10	0.30 ± 0.23	93.2
		0.75 pint	13	0.62 ± 0.45	86.1
Sept. 17, 1940	Paradichlorbenzene	2 ounces	10	0.80 ± 0.54	81.8
	dichlor-ethylether	0.5 pint	7	0.86 ± 0.60	80.7
		0.75 pint	6	0.00 ± 0.00	100.0
Nov. 14, 1940	ethylene dichloride	0.5 pint	11	0.36 ± 0.21	90.9
		0.75 pint	12	1.33 ± 1.00	69.8
Jan. 31, 1941	ethylene dichloride	0.5 pint	10	0.30 ± 0.23	93.2
		0.75 pint	11	1.00 ± 0.57	77.3
Mar. 26, 1941	ethylene dichloride	0.5 pint	5	0.00 ± 0.00	100.0
		0.75 pint	10	0.60 ± 0.45	86.4
Mar. 27, 1941	ethylene dichloride	0.5 pint	8	0.63 ± 0.45	85.9
		0.75 pint	10	0.50 ± 0.36	88.6

[1] Trees medium size, and soil ranged from heavy to light.
[2] Trees examined May 20 and 21, 1941.
[3] Ethylene dichloride and dichlorethylether applied as 25 per cent emulsions by weight.

cent reduction in borers. It is our opinion that these differences would not be significant with any samples in the realm of practicability. We were especially handicapped by the death of a number of trees due to sour sap. Usually a single tree was responsible for the poorer showing of the 0.75 pint dosage; most of the live borers being found in that tree. In many cases the trees were nearly girdled and the available cambium for borer development was greatly reduced. This condition more than any other one factor tended to reduce the number of borers found per tree.

CONCLUSIONS.—The work done here suggests that ethylene dichloride is not as effective against the species of borer that occurs in California as it is against the species that occurs in the east and south. The work has shown that it is possible to control the borer during the cooler parts of the year with ethylene dichloride at a time when paradichlorobenzene would be ineffective due to the low temperatures. It is very possible that kills obtained in late summer and fall treatments could be increased if the treatment followed an irrigation. If the soil for mounding was moist, there is likelihood of it forming a better seal thus retaining the vapor of ethylene dichloride and resulting in a better kill. The soil moisture content certainly would be more like that found in the south and east, and the treatment more comparable.

Because the fall treatment with ethylene dichloride emulsion has not proved greatly superior to the paradichlorobenzene treatment it would seem wise that farmers continue with the latter method of control. Probably some of their objections to the use of paradichlorobenzene crystals could be eliminated if they used greater care in applying the fumigant. The best of insecticides are likely to give poor control if not carefully applied. Where a farmer desires to use ethylene dichloride, he should try it out on a small scale.

Our investigations can not be considered extensive enough to give a clear picture of just how suitable this fumigant is under California conditions. It has shown some of its limitations as well as some of its advantages. It certainly appears that a farmer can hardly expect to obtain 100 per cent control, and under some conditions poor kills may result.

In the east, there is some evidence that trees have been injured with ethylene dichloride emulsion, and although our investigation would indicate that it can be used with safety under California conditions, caution should be followed.

If for some reason a farmer is unable to treat his trees with paradichlorobenzene while the weather is still warm, it may be well for him to use ethylene dichloride emulsion. If the soils are not moist it will probably be wise to put off treating until after the first rain. Under most conditions 0.5 pint of a 25 per cent emulsion should be used per tree.

Our limited work with a 25 per cent dichlorethylether emulsion would indicate that this fumigant is too hazardous, since there was definite tree injury where 0.75 pint of the emulsion was applied per tree. —1-19-42

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Platynota stultana as a Pest of Field-Grown Carnations

RICHARD M. BOHART, *University of California, Los Angeles*

Platynota stultana Wlsm., variously known in the literature as the "orange webworm," "orange calyx worm," and "rose leaf roller," was described by Walsingham in 1884 from Sonora, Mexico. The species was subsequently confused with *P. tinctana* Walker, and it has also gone under the name of *P. chiquitana* Barnes & Busck. The synonymy is given by Busck (1933).

HOST RELATIONSHIPS.—Nelson (1936) gave the following host records from California and Mexico. Avocado, bell pepper, carnation, cherimoya, cotton, cyclamen, grapefruit, orange, portulaca, red pepper, sugar beet, tomato, and walnut. It has also been recorded from Arizona feeding on grapefruit and alfalfa (Basinger 1936), from Virginia attacking greenhouse roses and chrysanthemums (Nelson 1936), and from Massachusetts on greenhouse roses (Bourne 1936). According to Basinger (1936) it has been reported on huckleberry; Nelson (1936) reared it on strawberry and fuschia; and the writer reared it on apple fruit.

In spite of the apparently broad host list it appears to be a persistent pest in California only on orange, rose, and carnation. Damage to the new growth of nursery orange stock was reported by Woglum (1920) as early as 1913 at Whittier and 1915 at Pasadena. The same author stated that what was apparently the same species was "highly destructive to carnations, asters, and chrysanthemums at Hollywood in 1913 by destroying the buds, webbing together the leaves or eating into the stalk." The species apparently occurs throughout the orange district of southern California (McGregor 1934) but its importance on this crop has been minimized by recent authors (Basinger and Boyce 1936). The writer observed it in 1940 and 1941 causing serious injury to greenhouse roses in San Diego and the San Francisco Bay area. However, according to cut flower growers it is on carnation that the damage has been most severe during the past 10 years. The writer has seen many heavy infestations in the Los Angeles and the San Francisco Bay areas, which are the chief carnation-growing centers of California. In some cases the number of flowers which can be cut for market is reduced 75 per cent or more.

Injury to carnations can be separated into three well defined types. The most obvious of these is the leaf-tying. Small larvae tie the tips of young shoots and as the latter develop they take on a characteristic bowed shape. This type of damage is particularly prevalent in carnations which have broad-leaved, succulent foliage. Second: the larvae may enter buds at various stages and either entirely destroy the young buds or deform the developing flowers. Third: a small proportion of well grown larvae bore into the main stem and tunnel for several inches. This often causes the plant to wilt or to break in the tunneled region.

OUTLINE OF LIFE HISTORY AND SEASONAL HISTORY.—The eggs are laid on leaves, glass, or similar smooth surfaces. They are deposited in over-lapping fashion in a flat mass. An average female will lay about 200 eggs in 4 masses. In exceptional cases as many as 400 eggs may be laid and as many as 20 clusters may be deposited. Five larval instars were reported by Nelson (1936) for specimens reared at about 73° F. on rose leaves. The writer has found six instars to be the rule in laboratory rearings at about 75° F. on leaves of carnation, rose, and orange. The average lengths of various instars at maturity were, first 2.0 mm., second 2.5 mm., third 3.0 mm., fourth 5.5 mm., fifth 9.5 mm., sixth 15.0 mm. The color of the head capsule varies widely. In first instar larvae it is a pale mottled brown. Second to fourth instar capsules are ordinarily black, and in following instars orange-yellow. However, on carnation the fifth and sixth instars often have black head capsules also. Pupation takes place in the silk-lined burrow of the mature larva. This may be either between two leaves or in a flower bud. At 75° F. the pupal period lasts about 7 days and the pupa wriggles partly out of its nest before emergence of the adult. The adult female has a wing expanse of 15 to 17 mm. The wings are grey-

brown to orange-brown with an indistinct oblique dark band across the front pair. The adult male has a wing expanse of 12 to 14 mm. The front wings are dark on the basal half and yellowish-brown on the apical half. The hind wings are dark grey-brown.

An account of the life history under laboratory conditions with rose as a host plant was given by Nelson (1936). At an incubation temperature averaging 70° F., Nelson found that the period from egg to adult averaged 48.6 days. These experiments have been duplicated on a small scale by the writer in comparative tests with carnation, rose, and orange leaves as food. At an average temperature of 75° F. (73°–77°) the period from egg to adult averaged 46 days on carnation, 44 days on rose, and 43 days on orange. Half-grown larvae were also reared to maturity on apple fruit.

In the Los Angeles area it has been found that *Platynota stultana* will persist the year round on carnations grown in the field in cloth houses. Observations and preliminary experiments on control under these conditions were conducted by the author from August, 1940 to November, 1941. There were apparently five somewhat over-lapping generations during the year beginning August. Peak flights of moths were noted about September 8, October 28, April 27, June 12, and July 27. Injury was most pronounced in May and June and least noticeable from January to April. During this latter period most of the larvae were in a mature dormant condition in silk-lined tunnels which they had constructed in dead leaves around the bases of the plants.

PARASITES.—Parasites were noted at various times flying about in the carnation houses. Of the six species of Hymenoptera which were reared from *Platynota stultana* in the laboratory, two were braconids (*Microbracon platynotae* Cushman and *Microgaster phthorimaeae* Muesebeck), two were *ichneumonids* (*Exochus* sp. and an undetermined species), and two were chalcids (undetermined). The braconids were internal larval parasites, the ichneumonids were pupal parasites, and the chalcids fed externally on the larvae. During the period of observation the degree of parasitism of all species was very low (counts ranged from 0.5 to 2.0 per cent) except toward the first of August, 1941. At this time, in year-old cloth houses, 90 per cent of the larvae were parasitized, 20 per cent by *Microbracon platynotae*, 65 per cent by one of the chalcids and 5 per cent by the remaining parasites. However, this high degree of parasitism did not prevent the increase to injurious numbers of *P. stultana* by the middle of September in a cloth house of young carnations only a hundred yards away. Larval parasites recorded by Nelson (1936) from Virginia were *Meteorus dimidiatus* (Cress.), *Angitia ferrugineipes* (Ashm.) and *Cremastus* spp.

CONTROL STUDIES.—No published information deals directly with the control of *Platynota stultana*. Basinger & Boyce (1936), working primarily with *Argyrotaenia citrana* (Fern.), tested a number of materials on orange worms of which *P. stultana* was one. Their studies included a comparison of pyrethrum, rotenone, an aliphatic thiocyanate, nicotine-bentonite, cryolite (natural and synthetic), barium fluosilicate, and potassium fluoaluminate. Of these, cryolite, especially when used as a spray, gave uniformly best results.

Hamilton (1940) reported studies on *Platynota flavedana* Clem. infesting greenhouse roses. The work of this species is similar to that of *P. stultana* and in all probability the same control methods are applicable to both. Hamilton found that pyrethrum sprays which had proven effective against other leafrollers attacking greenhouse roses were not practical against *P. flavedana*. Semi-weekly fumigation with *Nico-Fume Pressure Fumigators* gave satisfactory results.

Control studies by the writer on carnations grown in the field under cloth were conducted during 1940 and 1941. In general, the procedure followed was to lay out plots in checkerboard fashion and to treat them at weekly intervals for 1 to 3 weeks. At the conclusion of the experiments, counts were made of all live worms in treated as well as untreated plots. Per cent kills were estimated on a comparative basis, assuming the mortality in the untreated plots to be zero.

Sprays containing paris green, acid lead arsenate, pyrethrum-rotenone combinations, cuprous cyanide, natural cryolite, dichloroethyl ether, nicotine-bentonite, and dicyclohexylamine 2-4-dinitro-6-cyclohexylphenol were used. The resulting data is summarized in table 1. Some of the sprays had undesirable effects on the

Table 1.—Comparison of various materials used in sprays for control of *P. stultana* larvae infesting carnations grown in a cloth house in southern California, 1940–41.

TEST NO.	QUANTITY OF MATERIALS USED TO 100 GALLONS[1]	NUMBER AND FREQUENCY OF TREATMENTS	NUMBER OF PLANTS EXAMINED	NUMBER OF LIVE WORMS	ESTIMATED PER CENT KILL
1	Acid lead arsenate, 3 lbs. casein spreader, 2 lbs.	4 10 days apart	180	70	30.7
	Check	—	180	101	0.0
2	Acid lead arsenate, 3 lbs. casein spreader, 2 lbs.	2 7 days apart	96	26	49.0
	Rotenone (2.5%), pyrethrum (0.4% pyrethrins), 1 qt.	2 7 days apart	132	36	49.1
	Dichlorethyl ether, ½ gallon	2 7 days apart	114	62	1.1
	Check	—	120	66	0.0
3	Natural cryolite, 8 lbs. blood albumin, 4 oz.	3 7 days apart	132	29	78.8
	Paris green, 1½ lbs. blood albumin, 4 oz.	1	132	53	60.6
	Rotenone (2.5%) pyrethrum (0.4% pyrethrins), 2 qts.	3 7 days apart	144	103	31.7
	Nicotine-bentonite (5% nicotine), 8 lbs. blood albumin, 4 oz.	3 7 days apart	144	81	46.0
	Check	—	126	131	0.0
	Natural cryolite, 8 lbs. blood albumin, 4 oz.	3 7 days apart	132	29	72.9
	DND4[2] (1.7%), 3 lbs.	3 7 days apart	72	43	26.5
4	Rotenone (1.75%), pyrethrum (0.9% pyrethrins), 1 qt.	6 twice ½ hr. apart, 7 days apart	72	19	67.5
	Check	—	336	273	0.0
	Natural cryolite, 6 lbs. blood albumin, 4 oz.	3 7 days apart	396	28	87.5
	Natural cryolite, 6 lbs. blood albumin, 4 oz.	6 3 days apart	150	8	90.7
5	Cuprous cyanide, 6 lbs. blood albumin, 4 oz.	3 7 days apart	342	37	81.0
	Rotenone (1.75%), pyrethrum (0.9% pyrethrins), 1 qt.	6 twice ½ hr. apart, 7 days apart	300	73	57.3
	Check	—	504	287	0.0
6	Natural cryolite, 6 lbs. blood albumin, 4 oz.	1	138	280	74.8
	Check	—	72	581	0.0

Table 2 (Continued)

Test No.	Quantity of Materials Used to 100 Gallons	Number and Frequency of Treatments	Number of Plants Examined	Number of Live Worms	Estimated Per Cent Kill
7	Natural cryolite, 6 lbs. blood albumin, 4 oz.	2 7 days apart	66	240	75.2
	Check	—	66	993	0.0
8	Natural cryolite, 6 lbs. blood albumin, 4 oz.	3 7 days apart	118	352	77.5
	Acid lead arsenate, 6 lbs.	1	66	276	68.4
	Check	—	132	1747	0.0

[1] Three-gallon hand pump sprayers were used; 1 gallon of spray was applied to 60 mature plants.
[2] Dicyclohexylamine 2–4–dinitro–6–cyclohexylphenol.

plants. Lead arsenate and nicotine-bentonite left an objectionable residue, pyrethrum-rotenone sprays destroyed the natural bloom of the foliage, and paris green produced a severe burn of the petals and sepals. Except for cuprous cyanide, table 2. The best kills (63.1 and 52.7 per cent) were inferior to those obtained by the use of sprays.

SUMMARY.—*Platynota stultana* Wlsm. has a broad host range but in California it is responsible for damage chiefly to carnation, rose, and orange. On carnation it persists throughout the year in cloth houses, but is dormant for a few months during the winter. Damage to carnation is of three types, leaf-tying, bud boring, and stem-boring, in descending order of frequency. At an average temperature of 75° F., the life cycle from egg to adult was found to vary from 43 to 46 days. Six species of hymenopterous parasites were reared in the laboratory but, except for a

Table 2.—Natural cryolite used as a dust for control of *P. stultana* larvae infesting carnations grown in a cloth house in southern California, 1941.

Test No.	Pounds of Cryolite to 6,000 Plants	Number and Frequency of Treatments	Number of Plants Examined	Number of Live Worms	Estimated Per Cent Kill
1	6	3 7 days apart	186	38	63.1
	Check	—	504	287	0.0
2	6	1	144	771	33.5
	Check	—	72	581	0.0
3	6	2 7 days apart	60	540	40.2
	Check	—	66	993	0.0
4	6	3 7 days apart	120	751	52.7
	Check	—	132	1747	0.0

of which the cost is at present prohibitive, the only material giving kills of over 70 per cent was natural cryolite. Another point in the favor of this material was the ease with which the small amount of residue formed was washed from the foliage when the flowers were cut for the market.

As a comparison, a number of tests were made using amounts of cryolite dust equivalent to those used in the spray experiments. The results are outlined in

short period toward the end of summer, these did not appear to be of much consequence. Materials used in control studies included paris green, acid lead arsenate, pyrethrum-rotenone combinations, cuprous cyanide, natural cryolite, dichloroethyl ether, nicotine-bentonite, and a nitrated phenol. The first three of these had undesirable effects on foliage. The most promising material was natural cryolite used as a spray at the rate of 6 pounds to 100 gallons applied to 6000 mature plants. —1–6–42.

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Variations in Tolerance of Narcissus Bulbs to Hot Water-Formalin Treatment Associated with Locality of Production or of Storage

CHARLES F. DOUCETTE, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

The use of heat treatments of narcissus bulbs for the control of various bulb pests has become standard practice with most narcissus growers. Observations have indicated that there is a possible influence on treatment effect associated with the storage conditions to which narcissus bulbs are subjected during the summer months. In the Pacific Northwest narcissus bulbs are produced in several sections of the coastal slope, and a considerable variation in climatic conditions, both for the growing season and for the storage season, is represented in this area. To determine the influence of differences in environment, bulbs from distinct regions in the Pacific Northwest were selected for comparing the effects of hot water-formalin treatment.

All bulbs used were of the variety King Alfred. The same treatment schedule was followed throughout, namely, a 2-hour presoak in water at 75° to 80° F. followed by immersion in water at 111° for 4½ hours. Formalin (40 per cent formaldehyde) was added to the treating water (111°) to make a dilution of 1 to 400 (1 pint to 50 gallons). All treatments were made at the laboratory of the Bureau of Entomology and Plant Quarantine at Sumner, Wash. To represent the theoretically ideal treatment season for domestic stocks, one lot from each region was treated 6 to 8 days after it was dug, and this was stored, with a corresponding untreated check, at Sumner. The dates of these treatments ranged from July 26 to August 10. This early-season treatment represented a tolerance effect that might be associated with the production locality, since the lots from all the localities were exposed to identical storage conditions until planting time. To represent the storage conditions at each bulb source half of the original sample was stored on the grower's premises, and all these samples were collected late in September and brought to Sumner, where they were treated on September 29. For each treatment lot an untreated check lot was handled in a similar manner.

The following regions were represented:

Table 1.—Increase in weight of narcissus bulbs from different areas of Washington and Oregon after one season's growth following early-season and late-season hot water-formalin treatment.

Area	Mean Per Cent Weight Increment of Bulbs					
	Early-Season Treated	Untreated	Relative Difference, Per Cent	Late-Season Treated	Untreated	Relative Difference, Per Cent
Oregon						
Curry County	109	127	−14	82	99	−17
Tillamook County	149	168	−11	101	147	−31
Multonomah County	105	133	−21	82	122	−33
Washington						
Clark County	123	142	−13	94	138	−32
Pierce County	135	153	−12	50	145	−66
Skagit County	128	142	−10	42	130	−68

(1) Curry County, Oregon (southern coastal area); (2) Tillamook County, Oregon (northern coastal area); (3) Multnomah County, Oregon (lower Willamette valley); (4) Clark County, Wash. (southwestern Washington); (5) Pierce County, Wash. (southern Puget Sound area); and (6) Skagit County, Wash. (northern Puget Sound area). The air-line distance between the Curry County and the Skagit County locations is approximately 450 miles.

Shortly after the late-season treatment all the lots were planted at Sumner and grown for one season. Each lot consisted of 50 bulbs, and the treated bulbs were planted in rows paralleling their respective checks. Weight records were made for each bulb at planting time and after digging, to furnish the data concerning weight increment. The increase in bulb weight is the principal criterion used for comparing the effects of the treatment. The increases in weight of the several lots are presented in table 1. To compare the performances of the bulbs from the several regions, the difference between the increase of each treated lot and its check has

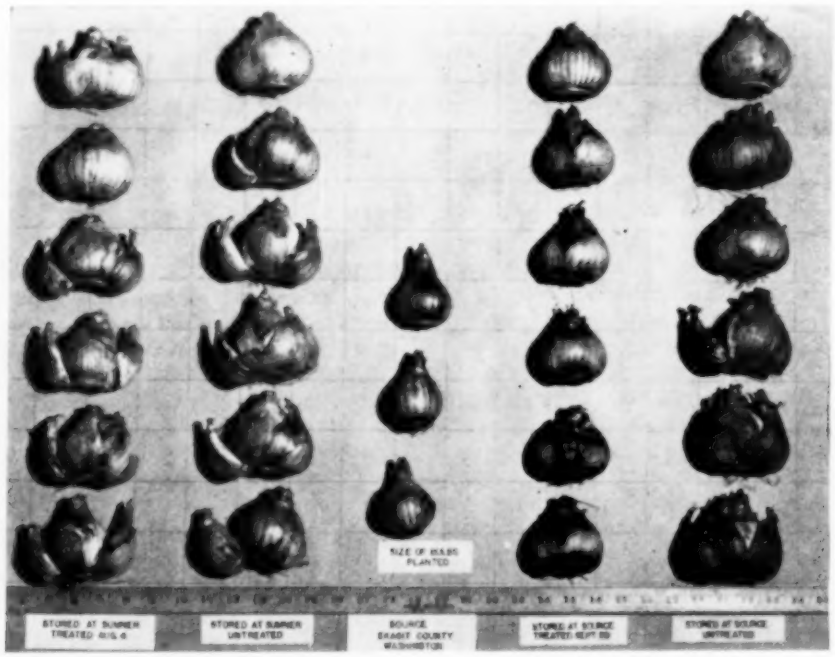
SIZE OF BULBS PLANTED
STORED AT SUMNER TREATED AUG. 6
STORED AT SUMNER UNTREATED
SOURCE SKAGIT COUNTY WASHINGTON
STORED AT SOURCE TREATED SEPT. 20
STORED AT SOURCE UNTREATED

FIG. 1.—Narcissus bulbs from Skagit County following one season's growth after hot water-formalin treatment compared with untreated bulbs.

been computed as a percentage, according to the following formula:

$$\frac{\text{(Mean per cent weight increment of treated lot)—(mean per cent weight increment of check)}}{\text{(Mean per cent weight increment of check)}} \times 100$$

The differences are therefore on a relative basis and can be compared with each other. A negative difference would represent a decrease and a positive difference an increase below and above the check.

None of the treated lots increased more than the corresponding check. In the early-season treatments only one lot is particularly different from the others in the degree of effect. The Multnomah County treated lot made 21 per cent less growth than its comparable check, while the five other lots were within 10 to 14 per cent of their checks. Since this deviation is not reflected in the other early-season groups it is probably not a locality effect.

The effect of late-season treatment is much more marked, and definite variations appear that seem to be associated with the localities. The late-season-treated lot from Curry County showed a decrease of only 17 per cent. The differences of the late-treated bulbs from Tillamook and Multnomah Counties in Oregon and from Clark County in Washington were similar. The late-treated bulbs from the two more northerly counties in Washington, Pierce and Skagit, reacted about equally, producing 66 and 68 per cent less growth than their checks, which is a pronounced lack of tolerance. The effect on the Skagit County bulbs is illustrated in figure 1.

The results from the late-season treatment indicate a decreasing tolerance as the locality of bulb production and storage changes from south to north. That is, bulbs from the more southern areas tolerate the late-season treatment better than those from the more northern areas. Since the early-season treatments did not exhibit any differences that could be associated with the source localities of the bulbs, it seems that the variation in effects of the late-season treatments was associated with the environmental conditions of storage in the several localities. It has been recognized by horticulturists that environmental conditions, particularly temperature, during the storage of narcissus bulbs after digging, exert considerable influence on the later bulb performance. Since these effects are rather complex, and not thoroughly understood, no attempt has been made to correlate any of the environmental elements with these differences in bulb tolerance to the late-season treatments.

SUMMARY.—Narcissus bulbs from several localities in Washington and Oregon were subjected to hot water-formalin treatment to determine relation of locality of production and storage to tolerance. The treatment consisted of presoaking in water at 75° to 80° F., followed by immersion for 4½ hours in water at 111° containing formalin at a dilution of 1 to 400. The similarity of response of all lots following early season treatment, 6 to 8 days after digging, indicated that no important variation was associated with growing conditions of the localities. The bulbs stored at the several localities until treatment given near the end of the storage season varied considerably in their response, exhibiting decreased tolerance as the locality shifted from south to north.—1–6–42.

NEWELL ENTOMOLOGICAL SOCIETY "NEWS" WAR ISSUE

The Newell Entomological Society of the University of Florida has just issued (June, 1942) a War Issue of its attractive mimeographed booklet the "News."

This booklet, like its predecessors, indicates an active and useful organization of enthusiastic entomologists and students headed in the direction of entomology and reflects credit on the Society and its sponsor.

If the activities of this Society should be curtailed during the coming year the explanation will be apparent in the list of members in the service, published elsewhere in this *Journal*.

Variability of Diapause in *Melissopus latiferreanus*

S. M. Dohanian, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

Variation in the diapause has been recorded for several species of insects. For example, mature larvae of the pink bollworm, *Pectinophora gossypiella* (Saund.), were found by Gough (1916) to pass through variable periods of hibernation or suspended activity, some as long as 2 years. Ross (1914) and O'Kane (1914) observed that some individuals of the apple maggot, *Rhagoletis pomonella* (Walsh), remained in the ground through two winters, emerging the second summer after the maggots entered the ground. Lathrop & Nickels (1932) found that a few individuals of the same species on blueberry even pass through a 4-year cycle, emerging as flies approximately 4 years after entering the ground as maggots. More recently Yothers & Carlson (1941) have reported that considerable numbers of fully grown larvae of the codling moth, *Carpocapsa pomonella* (L.), may remain in a dormant condition through an entire season and transform to moths nearly 2 years after spinning their cocoons.

In the course of work with the filbert worm, *Melissopus latiferreanus* (Wlsm.)[1], in the Northwest a similar condition was observed and is here placed on record. This insect, which is indigenous to the United States and Mexico, was described in 1879 by Lord Walsingham from specimens reared from Catalina cherry, a wild shrub growing on Catalina Island, Calif. In the Pacific Coast States it has been reared from more than a dozen hosts, but most commonly from acorns, wild hazelnuts, galls formed on oak stems and twigs by *Andricus californicus* (Gillette), galls on oak leaves caused by *Cynips maculipennis* (Bassett), and the filbert nut. Although formerly the insect was known as the "Catalina cherry moth," its present accepted common name is the "filbert worm," because of the economic importance it has recently assumed as a pest of filbert.

Specialists in the taxonomy of the group which includes *Melissopus* find the moth to be extremely variable in color, size, and structure; and have separated *latiferreanus* into seven varieties, A to G. Varieties A, B, and C have been found west of the Rocky Mountains, and D, E, F, and G east of the Rocky Mountains, to the Atlantic coast. During the past 4 years collections of the above-mentioned common hosts in Washington, Oregon, and California have shown that *M. latiferreanus* variety A infests hazelnuts and the two galls, while variety C was reared from Catalina cherries, acorns, and filberts. No specimens of other varieties have been reared by the writer in this area.

When the intensive study of the filbert worm was started, a visit was made by the writer to Catalina Island to get material for study from the host from which the insect was first described. Arrangements were made with Albert A. Conrad, horticulturist to the company owning the island, for further collection of material and shipment to the Eugene, Oregon, laboratory throughout the summer. Four shipments of Catalina cherries, all collected from trees near the Avalon Golf course were received in 1938 as a result of that arrangement. At the laboratory each lot was transferred to one or more 6 by 9 inch battery jars for rearing. In the bottom of each jar, was placed about an inch of sterilized soil. A wire screen basket containing the cherries was placed over the soil in the bottom of each jar. These baskets were approximately 5 inches in diameter and 6 inches high and were provided with legs long enough to allow a little air space between the top of the soil and the cherries in the baskets so as to reduce the formation of mold. The jars had grooved wooden covers, each with a large screened ventilation hole in the middle. The following spring the baskets of cherries were transferred from the original battery jars to new clean jars, and the adults were allowed to emerge from larvae that may have hibernated within the mass of pulp and pit. Since the soil in the jars was known to harbor some hibernating larvae, that too was left undisturbed for the normal emergence of adults.

The first lot of material received from

[1] Order Lepidoptera, family Olethreutidae, subfamily Laspeyresiinae.

Catalina Island was collected on August 9 and consisted of 325 premature drops of the cherry. The second shipment, which was collected on August 20, contained two lots, one of 95 prematurely dropped cherries picked from the ground and one of 118 green cherries picked from trees. The third shipment, collected on September 1, was composed of 3 lots, namely, 160 cherries which had dropped prematurely just prior to collection, 60 pits also picked from the ground but which apparently had dropped some considerable time before being picked, since they were practically devoid of any pulp, and 84 cherries picked from trees. The last shipment received from Catalina Island consisted of two lots collected on September 6, 1938, and included 150 drops picked from the ground and 140 green cherries picked from trees.

The records of emergence of moths from the Catalina cherry material are shown in table 1.

All the moths that emerged were of variety C. Some of the individuals from the first two collections emerged in time to produce another generation the same season; about two-thirds of the insects collected emerged the following season; 7, or 13 per cent, of the larvae hibernated through two winters before issuing as adults; and 3, or 5 per cent, remained in the soil through three winters. The summer-generation larva forms a thin, frail cocoon, only sufficiently strong to permit the easy egress of the moth from the pupal shell. However, the cocoons of the over-wintering forms are spun finely and closely, are firm, tough, and strong, with particles of soil and gravel adhering all around their exterior. They are impervious to water, and their texture would seemingly protect the enclosed larvae from desiccation in severe or prolonged droughts.

A few specimens of variety C that had hibernated through two winters have been

Table 1.—Emergence of moths of Melissopus latiferreanus var. C from Catalina cherry material collected in the summer of 1938.

Date Collection	Nature of Material	Number of Fruits	Dates of Emergence				Total Emerged
			1938	1939	1940	1941	
Aug. 9	Premature drops	325	Sept. 15[1], 20[1]; Oct. 8, 10, 12	July 26			8
Aug. 20	Premature drops	95	Sept. 26	June 29; July 11, 12, 30; Aug. 25	July 16, 29, Aug. 6		9
	Green-picked cherries	118		July 30; Aug. 1, 7, 18		Aug. 22, 25	6
Sept. 1	Premature drops	160		July 11, 12, 16, 23, 25, 28; Aug. 1, 3, 7, 9,[1] 10, 11,[1] 17,[1] 23			17
	Cherry pits from ground	60			Aug. 28		1
	Ripe-picked cherries	84				Aug. 1	1
Sept. 6	Drop cherries	150		July 8, 10, 26, 27; Aug. 7			5
	Green-picked cherries	140		July 8, 27; Aug. 3,[1] 4	July 4, 19; Aug. 6		8
Total		1,132	8	37	7	3	55

[1] Two moths emerged.

reared from infested acorns and filberts collected in the Willamette Valley in northwestern Oregon.

The discovery of larvae which hibernate through two, and even three, winters leads one to the conclusion that it must be a provision of nature to perpetuate the species. The normal hosts of *Melissopus latiferreanus* variety C are acorns and Catalina cherry. It is a well-established fact that these plants, like many uncultivated plants growing in the wild, bear fruit profusely certain years and then are entirely unproductive or yield meager crops for periods of a year or more—usually several years. Assuming that during such periods of scarcity of host plants of *latiferreanus* variety C there occurs an over-abundance of its several natural control agencies, the species would be threatened with complete extermination. It seems, however, that nature has provided against such a catastrophe for this species.—1-6-42.

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The Seasonal Distribution of Myiasis-Producing Diptera[1]

M. A. STEWART and E. B. ROESSLER, *University of California, Davis*

In an attempt to obtain quantitative data on the seasonal distribution of myiasis-producing Diptera at Davis in the southern part of the Sacramento Valley of California and with the hope of being able to anticipate the damage one might normally expect from these parasites, trapping was conducted continuously from November 26, 1935 until December 17, 1936.

TECHNIQUE.—Thirteen cone-type fly traps were set out, but two of these were soon discontinued. The remaining 11 traps were located in slightly different ecologic situations as shown in table 1. These traps were 24 inches tall and 12 inches in diameter with a cone 14 inches high. Each trap was baited with 0.5 pound of lamb liver, 7.5 grams of sodium sulphide, and enough water barely to cover the meat. The traps were examined daily and the baits were kept moist and were replenished as necessary. The catches were collected at intervals determined by the number of flies present. These intervals usually did not exceed 3 or 4 days and were never greater than 1 week. The traps were not permitted to become more than half full. At the times of collections from the traps a piece of rubber hose 3 feet long was attached to the exhaust pipe of an automobile; each trap was placed in a heavy canvas duffle bag; the hose was inserted into the bag which was tied tightly about the hose; and the motor of the car was speeded up with a retarded spark for about 2 minutes. This killed the flies without disturbing the taxonomic structures. Then the flies were poured through a metal funnel into large paper sacks.

After collection the flies were permitted to dry thoroughly before random sampling and identifying. A random sample of 500 specimens was taken from each catch. The myiasis-producers were identified and counted in each sample and the number of flies of each genus or species in the total catch was estimated by means of the following formula:

$$\frac{\text{Number of genus or species in total catch}}{\text{Number of genus or species in sample}} = \frac{\text{Weight of total catch.}}{\text{Weight of sample}}$$

[1] The authors wish to express their appreciation to L. J. Berry, O. Schwab, J. R. Douglas, G. M. Spurlock, and D. P. Furman for valuable assistance in the routine aspects of this investigation.

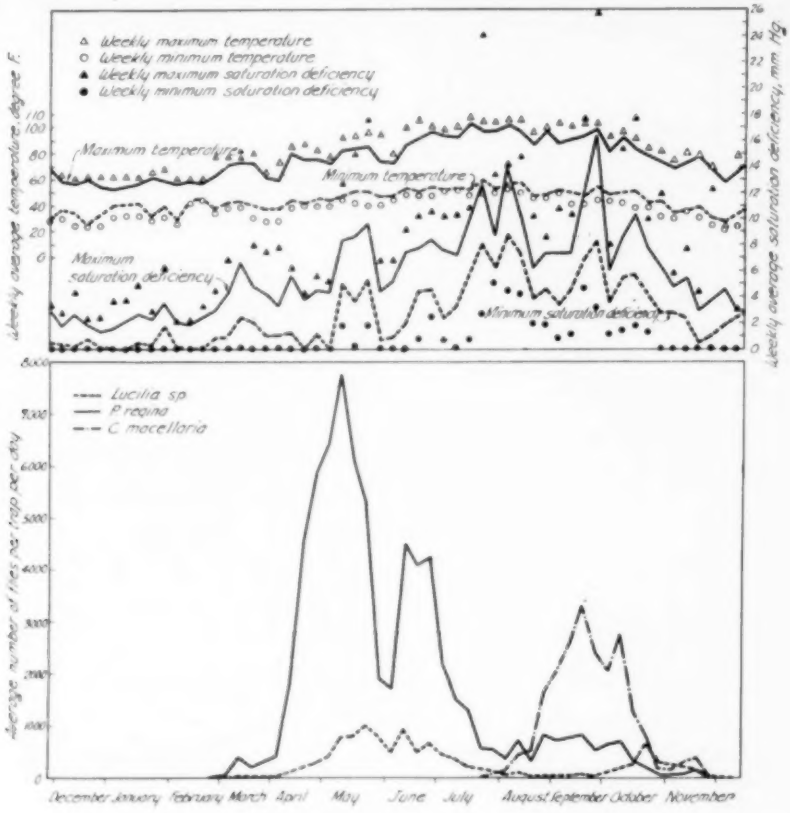
Weekly maximum temperature
Weekly minimum temperature
Weekly maximum saturation deficiency
Weekly minimum saturation deficiency
Maximum temperature
Minimum temperature
Maximum saturation deficiency
Minimum saturation deficiency
Weekly average temperature, degree F.
Weekly average saturation deficiency, mm Hg
Lucilia sp.
P. regina
C. macellaria
Average number of flies per trap per day
December January February March April May June July August September October November

FIG. 1.—Fly population trends and temperature and saturation deficiency recordings.

This procedure was justified by analyzing and comparing estimated counts with actual counts in large samples.

In the identification of the flies, representatives of the genus *Cochliomyia* were identified to species. Because of the large number of flies captured members of the genus *Lucilia* were determined only as to genus because these species are so closely related to one another in their myiasis-producing propensities. Of the genus *Phormia*, the only species collected was *P. regina*.

Daily records of temperature, saturation deficiency, rain-fall, and wind velocity were obtained from the University of California weather station on the Davis campus during the entire course of the investigations.

RESULTS.—Variance analysis was applied to the data to determine if there existed significant differences between the catches of different traps. This yielded an F value of 2.04 which failed to be significant, a value of 2.3 being required for significance at the 5 per cent level. Therefore, the catch over the entire area may be considered as fairly uniform, and as not being influenced by the slightly different ecologic conditions. Consequently, as shown in figure 1, the catches of all traps were combined in determining population densities which are expressed in terms of the average number of flies per trap per day.

Figure 1 shows the population trends for the period together with temperature and saturation deficiency trends. The ordinates of the maximum and minimum temperature and saturation deficiency curves are the averages of the daily maxima and minima values for the weekly periods. The maximum and minimum values during each week are also indicated.

Although the trends of population densities for certain intervals appear to be closely associated with those of temperature and saturation deficiency, through-

out the whole period no significant correlation exists except in the case of *Cochliomyia macellaria*. The coefficient of correlation between the population density of this species and saturation deficiency is 0.41 which is significant at the 1 per cent level. This correlation should not be interpreted as necessarily implying a causal effect.

Table 1.—Locations of fly traps.

TRAP No.	LOCATION
1	In apricot orchard, completely surrounded by trees
2	In peach orchard, not completely surrounded by trees
3	In row of black walnut trees beside irrigation ditch and cultivated ground; surrounded on 3 sides by compost piles of ensilage and manure
4	On bank of irrigation ditch, adjacent to orchard on one side and pasture containing hogs on the other. No shade
5	In empty hog pen, surrounded on 3 sides by hogs. No shade
6	Between sheep pasture and dairy cattle feed lot. No shade
7	Beside unoccupied building, protected from east and south winds. Shade in A.M.
8	Beside incinerator, very close to dump. No shade
9	In castor bean plot. Heavy shade
10	On bank of creek, surrounded by grass. Heavy shade
11	In corner of high hedge. Shade in P.M. Complete windbreak

The maximum population density of *Phormia regina* was attained in the interval between the first week of April and the first week of July; of *Lucilia* spp. between the middle of April and the first week in July with a second peak in October; and of *Cochliomyia macellaria* between the first week in August and the middle of October.

As indicated in figure 1, from the first week in March to the first week in July *Phormia regina* constituted from 84 to 91 per cent and *Lucilia* spp. from 9 to 16 per cent of the myiasis-producing population. From the second week in July to the first week in August *P. regina* ranged from 53 to 71 per cent of the population, *Lucilia* spp. from 7 to 22 per cent, and *Cochliomyia macellaria* from 7 to 40 per cent. From the second week in August to the first week in October *P. regina* ranged from 17 to 33 per cent of the population, *Lucilia* spp. from 2 to 9 per cent, and. *C. macellaria* from 40 to 80 per cent. Finally, from the second week in October to the end of November *P. regina* ranged from 14 to 33 per cent of the population, *Lucilia* spp. from 31 to 60 per cent, and *C. macellaria* from 18 to 55 per cent. During December, January, and February the collections of these three genera and species were too small to warrant consideration.

From the first part of September to the first part of December a very few small collections of *Cochliomyia americana* were made. Recognizing the greater difficulty of collecting this species in traps such as were employed, these findings nevertheless are substantiated by failure to obtain *C. americana* larvae from myotic wounds or to observe adults about wounds. The season of 1935 may be considered average so far as myiasis in the Sacramento Valley is concerned and this part of California rarely suffers serious damage from *C. americana*. It might be pointed out in passing that the primary screw worm caused severe losses in the late summer and fall of 1940, following two unusually mild winters, but this fly failed to appear in abundance in 1941. The winter of 1940–1941 was one of very heavy rainfall and floods and the water table rose to unusual heights and remained there for a considerable length of time. This may possibly have resulted in drowning the pupae of *C. americana*.

CONCLUSIONS.—Existing ecologic conditions at each trap exerted no significant influence upon the catches.

No significant correlation exists between temperature and saturation deficiency and the population trends of the myiasis-producers except in the case of the population density of *Cochliomyia macellaria* and saturation deficiency. However, it cannot be concluded that this correlation necessarily indicates a causal effect.

The population density of *Phormia regina* was greatest from March until July; of *Lucilia* spp. from April until July and

again in October; and of *Cochliomyia macellaria* in August and September. During their peaks *P. regina* and *C. macellaria* predominate among the myiasis-producers and constitute more than 80 per cent of the population. The first peak of *Lucilia* spp. occurs at approximately the same time as that of *P. regina* and does not exceed 16 per cent of the population, but the second peak contributes 60 per cent to the population which at this time is relatively small. The greatest population density, regardless of the species, occurs from March until July. These findings indicate that *P. regina*, because of its greater abundance over a longer period of time, is the most important myiasis-producer in the Sacramento Valley. *Cochliomyia macellaria*, because of its greater abundance as well as its higher efficiency as a wound invader, becomes the most important myiasis-producer during August, September, and the first part of October. The *Lucilia* spp. become most important during the colder part of the year. *Cochliomyia americana* assumes importance in this part of California only in exceptional years.—1-12-42.

Flight and Oviposition Habits of the Clear Lake Gnat

ARTHUR W. LINDQUIST and CHRISTIAN C. DEONIER, *United States Department of Agriculture, Bureau of Entomology and Plant Quarantine*

The Clear Lake gnat, *Chaoborus astictopus* D. & S., a nonbiting midge, causes considerable annoyance and discomfort to residents along the shores of Clear Lake, in Lake County, Calif. The tourist business is severely affected thereby. Annoyance to human beings is caused by the presence of this insect in tremendous numbers and also by its attraction to lights. At times clouds of gnats encirlce a light so that one cannot approach the lamp. Driving a car at night is frequently hazardous because of great numbers of the insects striking and accumulating on the windshield. The gnats create a further nuisance in that spiders have multiplied in the midst of such a food supply and their webs drape bushes, trees, and buildings. Herms (1937) reported on this bothersome insect breeding in the waters of Clear Lake.

Blue Lake and Lake Pillsbury, located near Clear Lake, harbor the same species of gnat, but annoyance by the insect along the shores of these lakes is negligible. *Chaoborus* larvae have been found in about the same abundance on the bottom of these lakes as in Clear Lake, although the total number in Clear Lake is enormously greater because of the larger area. Clear Lake is a comparatively warm body of water without a thermocline; the annual bottom temperatures range from 45° to 78° F., whereas the other lakes have lower summer temperatures. Plankton, the larval food supply, is more abundant in Clear Lake. It is believed that the large area, favorable temperatures, and the presence of abundant food for the larvae are the principal factors responsible for the heavy breeding of *Chaoborus* in Clear Lake.

Species of *Chaoborus* (*Corethra*) have been reported from many lakes in the United States and in Europe. Some lakes in the northern part of the United States support heavy concentrations of *Chaoborus* larvae. Eggleton (1931) reported these larvae attaining a population of over 70,000 per square meter in Third Sister Lake, Mich., but he did not indicate that the adults are bothersome. Muttkowski (1918), reporting on these insects in Lake Mendota, Wis., stated that "Large swarms of them fly to the lights of Madison or gather in the treetops, especially in the vicinity of the lake." He did not indicate, however, that the insect is a pest. The literature on the subject does not dwell on, or invite attention to, the nuisance caused by *Chaoborus* adults. It appears that Clear Lake is unique in creating a *Chaoborus* problem.

PHYSICAL CHARACTERISTICS OF CLEAR LAKE.—Clear Lake (Fig. 1), with an area of approximately 40,000 acres, lies at an elevation of approximately 1,300 feet. The mountains, some of which rise to an altitude of 4,100 feet, slope more or less abruptly toward the water's edge along a considerable margin of the lake, although at the upper end several alluvial plains fan out into the lake. The shore line is regular, with few bays and coves.

The lake is comparatively shallow. The bottom of the upper and larger portion is saucer-shaped, with the slope gradual at most places. The greatest depth, at zero Rumsey gage reading (a gage for determining the lake's level), has been found to be 27 feet in the upper portion and 50 feet in the lower portion. The lake level fluctuates because the water is used for irrigation purposes. Occasionally its level reaches 8 to 10 feet above or 1 to 2 feet below zero Rumsey gage reading.

The deposit on the bottom is a deep, soft, black ooze, except for an area in the southeastern part of Konokti Bay, which is composed of clean, volcanic, gravel-like material.

FIG. 1.—Clear Lake as viewed from the northeast shore.

FLIGHT HABITS OF THE GNAT.—The gnats usually make their first appearance late in April or early in May and are present until October. For example, in 1940 the first adult was seen on April 17 and the last on October 22. The peak activity is in August, although heavy night flights may occur at any time when conditions are favorable.

Emergence takes place at night and the gnats disseminate over a wide area extending up to 6 or more miles from shore. A separate study of emergence is being prepared for future discussion. During the daytime the adults are more or less quiescent, resting in bushes and trees along the shore and in the surrounding mountains.

Toward sundown intense activity commences with the lakeward flight of the gnats. Mating has usually taken place by that time, and females dominate in the flight to the lake. The density of the flight increases tremendously near shore. Residents on the shore are consequently bothered a great deal more than those living back 200 or 300 feet. Frequently the females concentrate and perform a rapid massed flight along the water's edge. Swarms may dip to within a few inches of the water and then rise to 10 or 15 feet with slight changes in air currents. In the Nice area this flight is always toward the west and into the prevailing evening breeze, although it is doubtful whether the breeze is a factor in the direction of flight, because under other conditions the insects have been observed flying with the breeze. This flight along the shore line may last from 15 to 30 minutes before the gnats move out over the lake. If the condition of the lake is unfavorable for oviposition—that is, stormy, or the temperature too low—the gnats disperse and may become extremely annoying on the shore.

Concentrations of gnats have been observed to vary widely along the lakeshore roads, but Lakeport and Lucerne areas harbor the greatest densities.

The males and some females continue to fly around lights for 1 to 3 hours, depending upon wind and temperature. The insect is sensitive to wind. Even light breezes cause swarms to dip and veer away from lights, and strong breezes reduce activity greatly, except in the protected lee of buildings or trees. The extent of egg development of the females affects their attraction to lights. The air temperature may be high enough for activity, yet females with eggs not fully developed may remain in trees close to an electric lamp without being attracted to the lights. Evening flight diminishes rapidly when the temperature drops below 55° F. During the night, when the insects emerge, air temperatures are lowest, frequently below 50°, but the insects are able to get to shore. Air temperatures of 42° have been known to be fatal to gnats emerging on the lake.

When conditions are not favorable for oviposition on the lake, the gnats seem to live for several days, with the result that heavy concentrations occur. In longevity tests conducted in September 1938, 107 males lived on an average 66.3 hours, with a range of 24 to 108 hours, and 116 females lived on an average 75.4 hours, with a range of 24 to 120 hours. In numerous tests in August and September 1939 longevity ranged from 24 to 72 hours.

LIGHT-TRAP STUDIES.—The sex ratio of the insects attracted to light depends

on weather conditions and the location of the lights. Gnats captured in light traps set up some distance back from the shore were 90 to 98 per cent males, whereas gnats taken in traps at the water's edge were 50 to 90 per cent females. Nearly all the females taken in traps contained mature eggs. This fact is of importance from a control standpoint.

Especially designed suction traps have taken large numbers of gnats. A large trap equipped with *Mazda* filament lamps totaling 900 watts captured 88.5 pounds (approximately 88 million gnats) in 2 hours one evening. Catches of this magnitude are infrequent, but 10- to 30-pound catches are common. A single trap operated with lamps totaling 400 watts took nearly 1000 pounds of gnats during the 1939 season. Females of *Chaoborus astictopus*, however, do not always respond positively to lights. It has been observed repeatedly that when conditions are at the optimum for oviposition the dominant reaction of the gnat is to fly out over the lake to oviposit, regardless of lights.

OVIPOSITION HABITS.—In the Nice area oviposition usually begins at the shore line just after darkness has fallen. The swarm advances quickly out over the lake, gradually diminishing for about three-fourths of a mile. With the aid of a light, some gnats were observed flying a few inches above the water, some dropping down, and others resting on the water. Apparently they were ovipositing, for within a few minutes the water was covered with white eggs. The eggs can be seen with a flashlight, and after heavy ovipositions they appear on the surface of the water as a glistening white sheet. Although oviposition is generally limited to within three-fourths of a mile from shore, on the few nights when the lake is calm it may occur as far out as 2 or 3 miles. If there is no breeze, females will oviposit on slightly rolling water. Egg laying has been observed when the troughs of waves have been 8 to 10 inches deep. The fact that the eggs of *Chaoborus astictopus* float is of practical importance in control efforts because the eggs of some chaoborids, at least those of *Corethra punctipennis*, sink within a short time after deposition (Eggleton 1931).

Dissection of females containing ova of an advanced age has shown numbers ranging from 256 to 337 per female, with an average of 296. It is not likely that egg production is much greater than this, and the female probably dies shortly after oviposition.

Females have shown a distinct choice in the type of water selected for egg laying in the laboratory. When fresh tap water and lake water were put in cages with gravid females, by far the greatest number of eggs were laid on the lake water, and those laid on the tap water were misshapen and immature. The hatch ranged from 95 to 100 per cent in lake water and from 5 to 10 per cent in tap water. On tap water that had been allowed to stand 24 hours or more, greater numbers of mature eggs were laid and a better hatch resulted. Distilled water was not attractive for oviposition.

FIG. 2.—Heavy concentration of *Chaoborus astictopus* eggs along shore.

Repeated tests in the spring and summer in which freshly emerged gnats from recovery cages on the lake were used indicated a preoviposition period of 36 to 48 hours or more. When confined in cages, gnats that emerged one night never have oviposited the following night. It is possible that a shorter period occurs in nature at summer temperatures.

CONCENTRATION OF EGGS.—The concentration of eggs into well-defined drifts on the surface of the water is a striking phenomenon. This was first observed by J. E. Hancey on August 29, 1938. During the night the eggs assume a brown color, and in the morning drifts can be seen from a half to 1 mile out from the shore, especially on the east side of the lake. The drifts are best observed from a slight elevation and when viewed toward the sun. The brown coloration varies in intensity with the degree of concentration and with the amount of debris present. Thin drifts

are not readily visible on ripply water, but narrow bands, heavily massed and only 3 to 5 feet wide, have been observed from a moving boat in rough water.

The size and shape of the drifts out on the lake are constantly changing. Ordinarily they occupy a very small part of the total area of the lake, but occasionally on the east side it has appeared that as many as 200 acres have been covered with eggs. Usually the drifts of eggs float toward shore in the morning, reaching there between 8 and 12 o'clock, and approximately three-fourths of them accumulate at the shore line, where as many as 10 million to the square foot may occur (Fig. 2). The accumulations may be from 1 to 20 feet wide and may extend for miles. Quarts of eggs may be scooped up in a few minutes. Mixed with the eggs are pupal exuviae, dead gnats, and algae. The eggs adhere to various materials with which they may come into contact, such as wood, metal, and paper, and a person's hands become heavily coated when placed in an egg drift.

The concentration of eggs is caused by various surface and subsurface water movements. The surface movements can originate from (1) light breezes which push the surface water, gradually bringing the eggs together or to shore, and (2) the action of a wind with accompanying waves on a part of the lake, causing back eddies in calm protected bays. When the surface of the lake is undisturbed by a breeze the subsurface flow extends to the surface, thus concentrating the eggs.

Observations and studies of egg drifts on various parts of the lake have shown well-defined areas of egg concentration around Rocky Point on the northwest shore. On the south half of the lake there is a large area where the eggs do not concentrate well. On the two lower arms of the lake the egg drifts are not common because of frequent strong winds.

When and under what conditions the eggs sink is of considerable practical importance in control studies. The finding that eggs can be destroyed with fire produced by burning gasoline directly on the water has necessitated a knowledge of various phases of egg sinking.

The egg accumulations at the shore line almost invariably sink before 6 o'clock in the evening. This is brought about by daily south and southeast winds, with accompanying wave action, which arise at any time from 12 to 5 p.m. The sinking of the eggs is brought about by the waves slapping on the shore. Obviously, any treatment of the eggs must be made early in the day before they sink.

When the wind comes up early in the day, before drifts have reached shore, the eggs are sunk by white-capped waves. Frequent observations show that eggs will float on smooth rolling waves and it is doubtful that they sink before reaching shore unless white-capped waves are formed. Storms occasionally come up during the night and sink the eggs before morning.

Table 1.—Number of drifts of Chaoborus astictopus eggs observed on the east shore of Clear Lake.

	Light	Moderate	Heavy	Total
1938				
August	0	1	1	2
September	1	4	2	7
October	2	1	0	3
Total	3	6	3	12
1939				
May	0	0	0	0
June	0	1	1	2
July	9	1	0	10
August	8	1	1	10
September	5	4	3	12
October	3	1	0	4
Total	25	8	5	38
1940				
May	8	1	0	9
June	9	3	3	15
July	15	3	1	19
August	20	2	5	27
September	5	2	1	8
October	5	0	0	5
Total	62	11	10	83

To determine whether eggs would sink when protected against waves, metal cylinders were pushed into the gravel in shallow water near shore to trap masses of eggs. Viable eggs floated until hatched, but nonviable eggs and the shells of hatched eggs floated for several days. Frequent tests in small beakers showed that only an occasional immature egg sank. There existed the possibility that some eggs might sink on the lake during the night. This was tested by submerging a

screen basket 1 foot under water, off shore in the evening before oviposition. Examination in the morning, following nights of heavy oviposition, failed to reveal any eggs in the screen basket.

The number of times drifts have been observed from the east shore since August 1938 is given in table 1. They are classified as light, moderate, and heavy. The great amount of oviposition in May and June 1940 was the result of extremely favorable weather, whereas in 1939 inclement conditions prevented extensive egg laying.

HATCHING.—A large portion, probably 75 per cent, of the visible eggs hatch at or within a few feet of the shore along the east side of the lake. The young larvae are transported by currents and undertows out into the lake. It is remarkable how evenly the larvae are dispersed over thousands of acres of lake bottom.

In the laboratory eggs will hatch both under water and on the surface. In the lake eggs hatch on the surface and presumably under water, since submerged eggs have hatched that have been recovered from under water and brought to the laboratory. The time of hatching varies according to the water and air temperatures. Under summer conditions eggs that are laid in the evening and remain afloat will hatch late the following afternoon. When eggs are washed under in the morning, hatching is delayed because of lower temperatures under the surface. Newly laid eggs submerged in water in a small dish required 44 hours to hatch at room temperatures during a cool period in July. Eggs subjected to a temperature of 44 to 51° F. in a refrigerator for 126 hours did not hatch. Eggs exposed for 42 hours to these temperatures, then kept at room temperatures, yielded a 98 per cent hatch.

SUMMARY.—Evening flights of the Clear Lake gnat, *Chaoborus astictopus* D. & S., and concentrations of dense swarms at the shore line create a nuisance to residents and tourists near Clear Lake, Calif. The size of the lake, approximately 40,000 acres, high water temperatures, up to 78° F., and abundant plankton for larval feed create conditions favorable for heavy breeding of this gnat.

The insects are strongly attracted to lights, but when conditions are favorable for oviposition their strongest instinct is to fly over the lake to oviposit.

Gnats taken in electric light traps at the water's edge show a preponderance of females. Nearly 100 per cent of the females taken in traps contained mature eggs. One trap has taken as high as 88.5 pounds of gnats in 2 hours in one evening.

On the east part of the lake oviposition usually begins at the shore line at dusk. After heavy ovipositions the water is covered with a white sheet of eggs which becomes brown by morning. One of the most striking phenomena displayed by the eggs is their concentration into well-defined drifts. Approximately three-fourths of the eggs on the lake may become concentrated at the shore line, where as many as 10 million eggs may occur to the square foot. When thus concentrated, the eggs can be destroyed by fire produced by burning gasoline on the surface of the water.

Eggs sink mainly at the shore line owing to wave action, which usually occurs from 12 noon to 5 p.m.—1-7-42.

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DR. DOVE REPLACES DR. CUSHING

It has been announced by the Department of Agriculture that Dr. Walter E. Dove has been placed in charge of the Division of Insects Affecting Man and Animals in the Bureau of Entomology and Plant Quarantine.

Dr. Dove assumes the duties of Dr. Cushing who has accepted a commission as a Major in the Sanitary Corps of the Army.

Biology and Control of *Empoasca filamenta*[1]

H. C. Manis and E. L. Turner[2]

Recent surveys have shown that the leafhopper *Empoasca filamenta* DeLong occurs abundantly on potatoes in Idaho. For this reason an experimental program was conducted in southeastern Idaho on the biology, host plants, and control of the leafhopper, and also on the possibility of its being a factor in reducing yields.

The common name, intermountain potato leafhopper, would be suitable for *Empoasca filamenta* since, as DeLong (1931) pointed out, its area of distribution is between the eastern range of the Rocky Mountains and the Sierra Nevada of California.

Biology.—Intermountain potato leafhoppers winter as adults in trash and debris along fence rows adjacent to cultivated fields, emerging on the first warm days of spring to feed and deposit eggs on numerous wild host plants. The host plants of the leafhopper were carefully studied throughout the season. Leafhoppers were found to feed on the following 14 wild plants: *Ira xanthifolia* Nutt., *Ira axillaris* Pursh., *Plantago major* L., *Articum lappa* L., *Grindelia squarrosa* L., *Malva rotundifolia* L., *Tanacetum vulgare* L., *Kochia california* Wats., *Potentilla biennis* Greene, *Potentilla millegrana* Engelm., *Erigeron* spp. (two), *Mentha* sp., *Solidago serotina* Ait. The first nine of these plants were suitable breeding hosts for the leafhopper, and the spring generation which migrates to potatoes is produced on them. The leafhopper is also found on such garden and field crops as potato, bean, sugar beet, carrot, squash, tomato, egg plant, cucumber, celery, and parsnip.

The eggs of the leafhopper are smooth, elongate, slightly curved, tapered to the ends, translucent and white in color. They are laid singly in slits in the plant tissue of the leaves, ribs, stems, and petioles and require an average of 12 days to hatch. The average length of time required to complete the nymphal development is 16 days. The average time required for the first instar is 2 days, the second instar 4 days, the third instar 2 days, the fourth instar 3 days, and the fifth instar 5 days. There are three generations and a partial fourth each season.

Injury.—The only injury to potatoes, produced by the intermountain potato leafhopper, appears as whitish spots on the leaf surface. These spots are caused by the removal of the cell contents from around the feeding punctures. There is no evidence of the "hopperburn" that is caused by the feeding of *Empoasca fabae* Harris. This might be explained by the fact that, as Smith & Poos (1931) have shown, *E. filamenta* feeds upon the mesophyll tissue of the leaves, while *E. fabae* feeds upon the phloem tissue.

Control.—Randomized block experiments were set up on three farms in the commercial potato-growing area of southeastern Idaho. There were two block replications of seven treated plots and one untreated check plot on each of the farms. Samples of nymph and adult leafhopper populations were made before and after each insecticidal application. Samples of adult populations were obtained by taking 50 sweeps with a 15-inch net in the two center rows of each plot. Nymphal population samples were obtained by counting the nymphs found on 20 leaves picked at random in the two center rows of each plot. The leaves were taken from relatively the same level on each plant.

All sprays were applied at the rate of 80 gallons per acre with a power sprayer equipped with a 12-nozzle boom and capable of maintaining 400 pounds of pressure. All dusts were applied with a power duster adapted to cover four rows. Two nozzles were directed on each row, and a 25-foot canvas drape was trailed in order to obtain better coverage. The dusts were applied at the rate of 25 pounds per acre.

Three applications of the following materials were made at approximately 14-day intervals.

Bordeaux mixture (4–4–50).

Sulfur-talc dust containing 80 per cent sulfur and 20 per cent talc.

Lime-sulfur spray containing 2 gallons of 32° Baume liquid lime-sulfur per 100 gallons of water.

[1] Published with the approval of the Director of the Idaho Agricultural Experiment Station as Research Paper No. 205.

[2] Assistant Entomologist, Idaho Agricultural Experiment Station, Moscow, Idaho, and Entomologist, Leafhopper Control Administration, State of Idaho, Boise, respectively. The authors wish to acknowledge the helpful suggestions and criticisms of Dr. W. E. Shull and Dr. R. A. Fisher.

Pyrethrum-sulfur-talc dust containing 80 pounds of sulfur, 15 pounds of talc, and 5 pounds of *Dry Pyrocide* (containing 2.0 per cent pyrethrins by weight) in each 100 pounds of dust mixture.
Pyrethrum extract-lime-sulfur spray containing 2 gallons of 32° Baume liquid lime-sulfur, 0.2 gallon of pyrethrum extract (containing 2.5 per cent pyrethrins by weight) and 100 gallons of water. One pound of soap for each 100 gallons of spray was used to emulsify the pyrethrum extract.
Cube-talc dust containing 1 per cent rotenone by weight.
Pyrethrum-cube-talc dust made by adding 5 pounds of *Dry Pyrocide* (containing 2.0 per cent pyrethrins by weight) to 95 pounds of the cube-talc dust containing 1 per cent rotenone by weight.
Check. No treatment applied.

The data obtained from plots treated with pyrethrum extract-lime-sulfur spray, pyrethrum-cube-talc dust, and the untreated check plots are summarized in table 1.

Both the dust containing pyrethrum-cube-talc and the spray containing pyrethrum extract and lime-sulfur were capable of reducing and maintaining low leafhopper populations throughout the entire season. The leafhopper populations in plots treated with these materials were reduced to such an extent that very little white stippling could be observed on the leaves of the plants. Bordeaux mixture and dusts containing sulfur, that have proved effective in the control of *Empoasca fabae*, did not control *Empoasca filamenta*. The cube-talc dust and lime-sulfur spray, likewise, did not reduce the number of leafhoppers.

The analysis of variance of yield data showed no significant difference in yield between plots. The fact that there was no increase in yield on plots where the leafhopper was controlled indicates that the leafhopper is not responsible for reduced yields in potatoes. There was a highly significant difference between yields on the three fields where the experiments were conducted. It is the authors' opinion that this difference was due to a difference in soil fertility and the amount of disease present in each field. Field No. 1 was plowed out of alfalfa before being planted to potatoes, while No. 2 had been plowed out of alfalfa and planted to potatoes the previous year, and No. 3 had been in potatoes two years after being plowed out of alfalfa. The authors have observed that the amount of early dying of potato vines and consequent reduction in yields are closely correlated with the number of years the field has been in potatoes.

SUMMARY.—Fourteen wild plants and numerous farm and garden plants were found to be suitable hosts for *Empoasca filamenta* DeLong. The average incubation time for eggs of the leafhopper was 12 days. The average length of time for nymphal development was 16 days. There are three and a partial fourth generations each season.

Pyrethrum-cube-talc dust and pyrethrum extract-lime-sulfur spray were effective in controlling *Empoasca filamenta*.

Table 1.—Average number of nymph and adult leafhoppers per plot.

Time of Application	Time Sample Taken	Pyrethrum Extract-Lime-Sulfur Spray		Pyrethrum Cube-Talc Dust		Check (No Treatment)	
		Nymphs per sample	Adults per sample	Nymphs per sample	Adults per sample	Nymphs per sample	Adults per sample
1st application (on July 18, 1941 at peak of first generation)	2 days before	6	164	8	146	11	125
	2 days after	4	41	2	45	7	133
2d application (on July 30, 1941 between generations)	2 days before	25	78	16	55	20	98
	2 days after	6	32	2	34	16	125
3d application (on August 15, 1941 at peak of second generation)	1 day before	6	73	4	60	11	139
	2 days after	1	24	0	19	9	112

Bordeaux mixture and the dusts containing sulfur, which control *E. fabae*, do not control *E. filamenta*. Cube-tale dust and lime-sulfur spray did not control this leafhopper.

The intermountain potato leafhopper does very little injury to the foliage and is not responsible for reduced yields in potatoes, since no increase in yields was obtained on plots where it was controlled. —1-14-42.

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Will Click Beetles Mate More than Once and Are They Parthenogenetic?

C. E. WOODWORTH, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

Investigations with attractants for the adults of the Pacific Coast wireworm, *Limonius canus* Lec., showed that males can be trapped rather easily (Lehman 1932). Although the sexes occur in nearly equal proportions in nature, large numbers of males, but relatively few females, come to traps. Unless the male beetles could mate more than once, or the females reproduce parthenogenetically, the capture of unmated males would prevent an approximately equal number of females from becoming fertilized, and consequently reduce the wireworm population. To determine whether the males can mate more than once and whether the species is parthenogenetic, the experiments reported in this paper were performed.

MULTIPLE MATING.—In preliminary studies 20 newly emerged male beetles were confined individually on moistened blotters in 2-ounce salve cans, each with an unmated female. When eggs appeared in any can, the male beetle in that can was transferred to a new one containing another unmated female. This procedure was repeated as frequently as possible until each of the males died. The success of each mating was determined by the hatch of the eggs. Observations were made daily until the eggs hatched, or until the eggs gave unmistakable evidence that they were infertile.

Altogether 20 male beetles were confined with 69 females, or an average of a little over 3 each. Of these females, 59 laid eggs. Ten males died while confined with females that did not subsequently lay eggs. All 20 males were with at least 1 female that laid eggs, 17 males were with at least 2, 14 with at least 3, 6 with at least 4, and 2 with 5. Of the 59 females that laid eggs, only 37 laid fertile eggs. Nineteen males fertilized at least 1 female, 12 at least 2, and 6 fertilized 3. These figures show that multiple mating can occur, and this evidence was corroborated by dissections of both male and female beetles following copulation. Spermatozoa were found in the females and both fully and partially developed spermatozoa in the males.

To determine more definitely the number of females that one male is capable of fertilizing, two more experiments were performed. In one of these, 40 newly emerged males and 408 unmated females were used, and in the other, 30 newly emerged males and 364 unmated females. The same type of cage and the same procedure were utilized as in the preliminary experiment, except that the male beetles were exposed to a different unmated female each day, regardless of whether mating had taken place or not, and this procedure was continued until the males died.

For the 772 opportunities to mate, 612 females laid eggs and 160 laid none. All 70 male beetles were with at least 1 female that laid eggs, although 10 died without stimulating as many as 5 to lay. Half of the males were with at least 9 females that laid eggs and 1 male had access to 26 females, 24 of which laid eggs. Only 158 of the 612 females that laid eggs laid fertile eggs. Sixty-two of the 70 males fertilized at least 1 female, 50 fertilized at least 2, 29 at least 3, 13 at least 4, and 4

fertilized 5. These figures show that 41 per cent of the males could fertilize 3 females and 4 per cent as many as 5.

It was found that the frequency with which fertilizations occurred was subject to individual variation. For example, 2 males, each of which fertilized 5 females, had the following history: Male No. 1 failed to fertilize the first female to which he was given accesss, fertilized the next 4 in succession, did not fertilize the sixth and seventh, and fertilized the eighth, after which the male died. Male No. 2 fertilized the first 2 females, did not fertilize the third, fertilized the fourth, did not fertilize the next 7, fertilized the twelfth and thirteenth, and did not fertilize the next 14 females, after which the male died. On successive days one male fertilized as many as 4 females, each of 2 males fertilized 3 females, and each of 25 males fertilized 2 females. With 101 males 1 day or more intervened between successive fertilizations.

Only 37 males fertilized the first female to which they had access. With another 16 males an unsuccessful copulation apparently had taken place, since the females laid infertile eggs within the time required for successfully mated individuals to oviposit and in comparable numbers.

In general it may be stated that the males will mate several times, but that fertilization occurs at irregular intervals, most frequently, however, with the first few females.

PARTHENOGENSIS.—During the early phases of the experiments, several unmated female beetles, which were being held for future use, were observed to lay eggs. It was suspected, however, that a male beetle had been accidentally confined with the females. The next year the beetles were segregated as to sex and overwintered in the laboratory refrigerator. In the spring each female was placed in an individual container so as to prevent contact with the male before use in the multiple mating experiments. Many of the females laid eggs, all of which were found to be infertile. In order to check the possibility of parthenogenesis, a critical set of experiments was conducted the following year.

Beetles were dug from field cages in the fall and segregated as to sex. The two sexes were overwintered in separate galvanized-iron field cages and dug again well before egg development had taken place. Two hundred and seventy of the females were separated into individual 2-ounce salve tins and kept at 50 degrees F. until normal spring emergence occurred in the field. On March 1 and 13 and April 4 three lots of the beetles were tranferred to a temperature of 68 degrees. The first two lots consisted of 100 females each and the third lot of 60. On March 13 the remaining 10 females were each confined with a male and brought to 68 degrees to act as a check. Daily observations were made until all the beetles died, and then frequent observations were made until all the eggs hatched or gave unmistakable evidence that they were infertile.

Of the 260 females that were kept without males 201, or 77 per cent, laid eggs, none of which hatched. All the females that were supplied with males laid eggs which hatched in the normal time. These data show that, whereas unmated females of the Pacific Coast wireworm may lay eggs, these eggs are infertile and will not hatch. It would appear, therefore, that parthenogenesis does not occur in this species.

CONCLUSION.—These experiments show that since the males of the species *Limonius canus* can successfully mate several times the practical value of trapping these individuals is lost. This is true even though the females can not reproduce parthenogenetically.—1-6-42.

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Time of Seeding as a Method of Control for the Pea Aphid on Fall-Sown Legumes in the Pacific Northwest

L. P. Rockwood and Max M. Reeher,[1] *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

In Oregon and Washington west of the Cascade Mountains it is customary to sow vetches and Austrian winter field peas in the fall for seed crops in the following year. The pea aphid, *Macrosiphum pisi* (Kalt.), has caused widespread injury to these crops in each of the 4 years ending with the crop harvested in 1941. During the 25 years preceding 1940 general aphid abundance on these crops had not occurred in more than 2 successive years. Including the 4 years ending with the crop harvested in 1941, extensive aphid injury to fall-sown annual legumes occurred in 9 of the last 25 years. In addition to these years of widespread aphid abundance, there have been some cases of localized aphid injury in other years.

It has been observed that aphids become abundant on fall-sown annual legumes over wide areas in crop years following mild winters. The viviparous female pea aphids become established in the fall on vetches or peas that are above ground before late October. This infestation results from winged aphids which find the plants almost as soon as they show above ground. The abundance of aphids on these hosts in the fall is directly related to the time of seeding, the sowings that are up first being the most heavily infested because the aphids have a longer period of favorable weather for increase on them. These early-seeded fields and cover crops sometimes show aphid injury in October or November and, following a mild winter, are badly damaged by aphids in the following spring. Our observations during the last 4 years showed that, even if the fall aphid infestations in certain early-sown fields were light, some aphid injury invariably occurred in these same fields in March, April, or May, following a mild winter; whereas fields that showed no aphids in the fall often escaped appreciable aphid injury. Moreover, early-sown and volunteer annual legumes that came up in September developed winged aphids later in the fall and early in the spring and became centers for dissemination of aphids into nearby fields.

That the time of seeding common vetch was a factor in aphid abundance and in aphid injury in the spring was noted in 1921 by Harry A. Schoth, Bureau of Plant Industry, United States Department of Agriculture, who wrote (April 21, 1921): "The heaviest attacks are on the earlier sown vetch .... All late sown vetch is practically free from them." In the same year members of the Forest Grove, Oregon, Laboratory for Cereal and Forage Insect Investigations, Bureau of Entomology, United States Department of Agriculture, observed two fields of common vetch near Cornelius in Washington County, Oregon, which showed this very distinctly. One field that had been seeded early in September was practically destroyed by aphids by May 21, while the other field, separated from it by a dead furrow only, was not appreciably damaged.

These observations indicated the possibility of determining a date for seeding annual legumes that would be likely to insure their escape from fall aphid infestation, *provided* no earlier fall growth of volunteer plants occurred in the same fields. This date could be determined for each year from a series of plots of these legumes sown on successive dates throughout the fall. Such plots have been sown at Forest Grove each year for the last 10 years; and, although there has been, in some years, some movement of aphids on foot between adjacent plots, the approximate dates for seeding to avoid fall aphid infestation have been determined for several of those years. Since it was known that the aphids initiating the infestation of fall-sown annual legumes in fields that are located 50 feet (Smith 1916) or more from the sources of infestation (summer hosts) must reach them by flight, it was also thought possible to determine when fall flights ceased because of meteorological conditions and hence the theoretical

[1] The writers are indebted to Harry A. Schoth for permission to quote from his letters and for other assistance, and to the following former associates whose unpublished notes have been used: Sadie E. Keen (Mrs. S. K. Zimmerman) and T. R. Chamberlin.

earliest date for seeding annual legumes to avoid fall aphid infestation.

That temperatures below 55° F. inhibit any attempt at flight of alate *Macrosiphum pisi* was demonstrated in the laboratory in November 1926. The still air of a room at 49 per cent relative humidity was gradually warmed from a minimum of 49° while winged aphids on potted vetch plants were watched. Slight movement began at 50°, and most of the alates were stirring and one spread her wings at 55°. Spreading of wings by individuals occurred 8 times in 26 minutes between 58° and 60°, and a few alates dropped to the table without flying. At 60° one flew to the window, about 33 inches away. One alate individual spread her wings 10 times at temperatures between 60° and 61° before she finally flew 3 inches. Spreading of wings was general between 60° and 61°, but only 5 flew in 15 minutes, 4 only 3 to 4 inches. Between 61° and 62°, in 11 minutes, 6 flew, one for 36 inches, the others 3 to 8 inches. Field observations confirmed these findings, none flying more than a few inches at air temperatures of 62° to 65°, and none could be caught by sweeping above the plants. Davies (1939) observed that the migration of *Myzus persicae* Sulz. in June was determined by the occurrence of days when the temperature exceeded 65°, the relative humidity being less than 75 per cent, and the wind velocity less than 5 miles per hour. From the foregoing data it is assumed that flight of *M. pisi* does not occur in the fall on days when the maximum temperature in a standard weather instrument shelter is below 60° F. It also seems probable that a higher temperature would be necessary for sustained flight from field to field, but to be on the safe side in the calculations, reported below, of the most conservative earliest date that annual legumes could have been seeded in each year to avoid any possibility of their becoming infested by alate pea aphids from other fields, an instrument-shelter maximum air temperature of 60° or of 55° or more at 5:00 p.m. was assumed to be sufficient for flight in the fall.

Good meteorological records for Forest Grove are available for a period of 25 years (1916–40), and less applicable records are available for a period of 40 years. From these records the last possible day for flight of the pea aphid was determined on the above basis for each year. The period between planting of the seed and first appearance of the plants above ground was determined by observations on our plots and then generalized on a mean-temperature basis. With these data available the aphid-free seeding date could be estimated for each year. A few deviations from the temperature rule were made in some years (1919, 1936, and 1938) when the date of the last aphid flight would have been determined by other limiting factors, such as frosts of sufficient intensity to eliminate alates or heavy rain on days with a maximum temperature of 60° or more. The approximate correctness of these estimated aphid-free sowing dates has been substantiated by the results obtained from our seeding-date plots during the past 10 years, particularly those years when it happened that plots were sown on or near the calculated dates.

The most conservatively estimated mean date for seeding annual legumes to avoid fall aphid infestation at Forest Grove, Oregon, was determined to be October 24 (October 23.72 ± 1.47) for the 25 years ending with the fall of 1940. For the 40-year period from 1901 to 1940 the mean aphid-free date was calculated to be October 24 (October 24.3 ± 0.99). There was a range from October 11 (1935) to November 7 (1917, 1939). Including only those years since 1901 that are known to have preceded aphid outbreaks, the mean aphid-free date for the 12 years was October 25 (October 24.5 ± 1.97). A slightly less conservative estimate, an instrument-shelter temperature of 61+° being used as a base for the last flight, gave a mean date of October 20 (October 19.92 ± 1.5) for the last 25 years. Taking 65° as the basic temperature for sustained flight from field to field, a mean date of October 17 (October 16.72 ± 1.34) was calculated for the 25 years ending with the fall of 1940. Annual legumes for seed should therefore not be seeded until after October 16 if any attempt is to be made to avoid fall aphid infestation and subsequent aphid injury, and seeding October 20 or later would be preferable.

Our plots at Forest Grove have indicated that the best time to seed common (Oregon) vetch, judging by vegetative growth only, is after October 15. If it is seeded before October 15, weeds are troublesome and there is some thinning of

the stands by "stem rot" during the winter. Schoth & Hyslop (1925) tabulated yields of seed of common vetch at Corvallis in relation to time of seeding. Their highest yield of seed, 29.66 bushels per acre, was obtained from an October 29 seeding in the harvest year 1918; and the next best yield from fall-sown vetch, 27.16 bushels per acre, was from a November 3 seeding in the harvest year 1915. Good seed yields, 16.08 bushels and 18.16 bushels per acre, were recorded for seedings of November 10 and November 30, respectively, in the harvest year 1916. McKee & Schoth (1925) tabulated the following yields, at Corvallis, for November-sown vetch: 1915–16, 720 pounds per acre; 1916–17, 1,630 pounds per acre; 1917–18, 1,027 pounds per acre. The most destructive outbreak of the pea aphid ever experienced in the Pacific Northwest occurred on the crops harvested in 1918, and all annual legumes suffered great damage. The fact that good yields of seed were secured at Corvallis from vetch seeded October 29, or in November, and that all other plots of that year were a total failure is an excellent argument for late fall seeding.

The optimum date for seeding Austrian winter field peas appears to be about the same as for common vetch, or even later. On our plots at Forest Grove, Austrian peas seeded in September and early in October have been disastrously thinned by "stem rot" in the winter ever since our first plantings of this legume in 1931, and seedings as late as October 14 have been considerably damaged by this phytopathological factor. Plots seeded after October 15 have not been seriously affected by this factor, and the latest plots not at all. Similar damage has been observed in fields. That late seeding of Austrian winter field peas is highly profitable was shown in 1938 in Yamhill, Clackamas, and Washington Counties, Oregon, and in 1940 in Clackamas and Marion Counties. In 1938 we obtained the yields of harvested peas, as reported by the growers or found in mill records, from 7 fields that were seeded on or before October 15 and from 7 fields seeded after October 15. The mean yields were 671 ± 93 pounds per acre and $1{,}375 \pm 104$ pounds per acre, respectively. The difference between mean yields in favor of the later seeding was 703 ± 140 pounds. Similar records were obtained in 1940 from 5 fields seeded on or before October 15 and from 5 fields seeded in November in Clackamas and Marion Counties. In this case the mean yields were 570 ± 89 pounds per acre and $1{,}096 \pm 64.5$ pounds per acre, respectively. The difference between mean yields was 526 ± 109.8 pounds per acre in favor of the later seeding. In 1940 our field observations showed that aphids were less abundant and caused less damage than in 1938. In both years not all the difference in yields between early and late fall-sown fields could be attributed to aphid injury. A large part of it was undoubtedly caused by the severe thinning of the stands of early fall-sown fields by "stem rot."

Hairy vetch, which grows more slowly than common vetch or Austrian winter field peas, may do better if seeded earlier than the other legumes. However, when seeded in September, often by harrowing in additional seed in old fields, hairy vetch becomes an important breeding place for aphids which may damage later-sown fields, as was observed in 1940. We have few data as to the effect of late seeding on seed yields of hairy vetch. In a letter dated September 20, 1941, H. A. Schoth has informed us that a seeding of hairy vetch at Corvallis on November 1, 1920, yielded 16 bushels per acre of recleaned seed, and a seeding on October 28, 1921, yielded 8.66 bushels per acre. These yields indicate that late seeding would not necessarily be detrimental to seed yields of hairy vetch.

It may be desirable to seed these legumes early for cover or green-manure crops in orchards, hop yards, nut groves, and berry patches. These cover and green-manure crops are frequently centers for the dissemination of winged aphids to nearby seed fields in the latter part of April and in May. However, they would not be factors of importance in aphid infestation of seed fields if they were turned under early in the spring, as is recommended by horticulturists and agronomists as a soil-moisture conservation measure. Schoth & Hyslop (1925) recommended plowing under such crops before April 1 in western Oregon.

Important factors that may interfere with late October seeding are, too frequent precipitation, wet soil conditions, and heavy frosts. In order to appraise these factors, a study of the meteorological records at Forest Grove, in relation to

possible interference with seeding between October 20 and November 15, was made. This calculation showed that the mean number of days available for seeding in this period of 26 days in the last 25 years was 14 ± 1. The smallest number of days available after October 20 was 5 in 1924; the greatest was 24 in 1917.

CONCLUSION.—Since long-range weather forecasts cannot yet be made, it is necessary to assume that any winter may be favorable for survival of aphids on fall-sown annual legumes. It is therefore recommended that common vetches (*Vicia sativa* varieties and selections) and Austrian winter field peas for seed be sown, in well-prepared ground that is free from earlier self-sown annual legumes, about October 20 and not before October 16, and that hairy vetch for seed be sown not earlier than October 11. If late seeding is to secure its maximum effect in reducing aphid abundance, cover crops and green-manure crops should be plowed under by April 7 (the calculated mean date for first spring flight of *Macrosiphum pisi* is April 7 ± 3 days). A general adoption of these recommendations would greatly reduce the ever-present threat of aphid damage to fall-sown annual legumes in western Oregon and in western Washington.—1-6-42.

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The Flight of Sugar-Beet Wireworm Adults in Southwestern Idaho.[1]

F. H. SHIRCK, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

Since the publication of a previous report by the writer (Shirck 1939) on the flight habits of the sugar-beet wireworm adults, data for 3 additional years have been accumulated. In April and May of 1939, 1940, and 1941 daily collections were made whenever flights occurred. This work was done in southwestern Idaho, near Parma, and in 1941 collections were also made in the vicinity of Adrian, Oregon. Throughout this general area, comprising portions of Canyon County, Idaho, and Malheur County, Oregon, the sugar-beet wireworm, *Limonius californicus* Mann., is the most prevalent and injurious species of wireworm in irrigated lands. The Pacific Coast wireworm, *L. canus* Lec., is also present in many fields, but in most cases constitutes only a small proportion of the total wireworm infestation. Because of the relative scarcity of the latter species in this district, no full opportunity was found to study its flight habits. The few females of *L. canus* that were collected in flight proved to be largely without eggs when captured.

It has been determined by the author through many years of observation of the sugar-beet wireworm in southwestern Idaho that emergence of the adults from the soil usually begins during the early part of April. The males appear above ground somewhat earlier than the females, and fertilization of each female occurs soon after her emergence from the soil. Usually several males search out and attempt to mate with any given emerging female, which gives rise to the characteristic phenomenon of groups of males clustered here and there over infested fields. Females have occasionally been seen when first coming above ground in the spring, and at this time they show little, if any, inclination to fly. The males, on the contrary, fly as far as 100 feet at a time in searching for females. These circumstances, together with the fact that males predominate throughout the flight period in collections made by sweeping foliage in the fields, led to the impression that flight was an activity more normal to the males than to the females. Therefore,

[1] In cooperation with the Washington and Idaho Agricultural Experiment Stations.

it was at first surprising to find that, when flight collections were made daily, there was a preponderance of females, approximating 90 per cent for a given day's collection. Hawkins (1936) reported similar observations in the case of the wheat wireworm, *Agriotes mancus* (Say), in Maine, where it was found that about four-fifths of the beetles which flew were females. He did not mention the number of eggs they were carrying when in flight, but concluded that flight was of negligible importance in the dispersion of that species. From the present study it is evident that flight by gravid females must be a factor of some importance in the dissemination of the sugar-beet wireworm in southwestern Idaho. Movement from field to field must be largely by flight, and the factor of flight must enter in significant degree into the rate at which new territory is invaded by this pest.

The studies reported in the present paper were designed to find out (1) the number of each sex resting on vegetation in the fields, (2) the number of each sex actually taken in flight, (3) the relation of numbers of eggs deposited by females taken in flight to those deposited by females sifted from soil before emergence, and (4) whether any of the females flew before being mated.

Since it was chiefly desired to investigate the relative numbers of males and females flying, and the egg-laying potential of the females during the season, no specific unit of measure by which the volume of flight could be appraised quantitatively from day to day was used. No satisfactory apparatus for flight sampling was known to the author when the studies were begun in 1938, although the rotary net, which has since been described by Chamberlin & Lawson (1940), would presumably be suitable for use in a study of the flight of wireworm beetles.

METHODS.—The flight collections were begun as soon as the flight started each day and continued as long as any flights were observed. Standard hand-operated nets were used, and collections were made of beetles actually in flight. On most dates there were two collectors, although they were not always stationed in the same field. On cold or excessively windy days, when no flight was expected, field trips were usually omitted. Wind records were obtained by use of a portable anemometer, and readings were taken in the field on days when collections were made. Several readings were taken during the afternoon, and an average figure is presented for the wind velocity. Maximum daily temperatures for Parma were obtained from the records of the United States Weather Bureau.

Sweepings from the vegetation were made with the same nets which were used in the flight collections. The sexes were separated and recorded immediately after these sweepings were concluded each day, and the insects were then discarded.

The females obtained in flight were placed one to a 2-ounce salve can, given moist soil, and kept there 2 or 3 weeks, or until they had laid all their eggs, after which egg counts were made. In some cases hatching started before the counts were made, and it was necessary to put 3 or 4 drops of ether into the 2-ounce can of soil, replace the cover, and stand it aside for a few minutes until the larvae became motionless. By this means an accurate count could be obtained, and the young larvae recovered without harmful effects. As far as possible, counting was done before hatching started.

In order to find out what proportion of their total egg quotas the flying beetles still carried, comparison with the egg production of females known to be fully gravid was necessary. Accordingly, some beetles were dug from the field prior to their emergence from winter hibernation and kept under observation until all their eggs were laid. Their average egg production was compared with that of females taken in flight during the same season.

RESULTS.—In 1940 sweepings from vegetation were made on 19 days between April 18 and May 18, inclusive, and a total of 488 males and 18 females were obtained. These sweepings were made in a red clover field where a heavy beetle flight occurred during the season. Sweepings were made in a wheat field and an alfalfa field in 1941, beginning April 24, and continuing until no further beetles could be obtained, or until May 23. Throughout the 1941 season also males outnumbered females in the collections made by sweeping from vegetation. Five hundred sweeps were made on each date in each of two fields in 1941, and a total of 234 beetles were obtained, 87.2 per cent of which were males.

It is difficult to obtain an accurate estimate of the proportion of males to females after they have left their pupal cells. Field counts made before spring emergence have shown that the sexes occur in about equal numbers. It may be that the males die sooner than the females and that the decrease in numbers of males flying after the third week of April is due to a scarcity of males as well as to an indisposition on their part to fly. It was noted that in the 2-ounce oviposition cans the females commonly outlived the males when pairs were confined together.

A record of daily flight collections in 1940 is given in table 1, with average wind velocities during the afternoons and daily maximum temperatures. Notwithstanding the preference of the beetles for calm weather, flights sometimes occurred on rather windy days. On May 2, 1940, 35 beetles were collected in flight, although the average wind velocity for the afternoon was 7.9 miles per hour. The day was warm, however, with a maximum temperature of 82° F. There was partial or intermittent cloudiness and several light showers occurred. Most of the beetles flew low to the gound on this particular day, but some attained an estimated height of 10 feet. On more favorable days many beetles rose as high as 20 or 30 feet and flew for considerable distances. It was necessary for the collector to run for distances up to 100 yards in order to intercept the beetles in flight, because only a few of them flew over any given point.

Flight collections and egg production of the captured females for the years 1938–41 are summarized in table 2 and in fig. 1. The heaviest and most prolonged flights took place from infested fields where there was a good cover of vegetation, such as alfalfa, clover, or wheat. No

Table 1.—Daily record of sugar-beet wireworm adults collected in flight, with mean wind velocities and daily maximum air temperatures. Parma, Idaho, 1940.

Date	Mean Wind Velocity, Miles per Hour	Maximum Temperature (Shade), °F.	Number of Adults Taken[1] Males	Females
April				
17	6.0	74	3	10
19	3.3	76	90	72
20	5.4	69	0	0
21	4.9	66	3	2
22	10.0	73	0	0
23	6.9	71	9	8
24	3.0	68	27	97
25	4.2	67	0	0
26	—	63	—	—
27	—	66	—	—
28	—	65	—	—
29	5.5	58	0	0
30	—	61	—	—
May				
1	2.9	74	27	182
2	7.9	82	2	33
3	5.5	77	4	50
4	—	71	—	—
5	3.2	69	3	44
6	3.3	71	14	208
7	2.0	75	9	122
8	2.0	81	3	186
9	7.4	84	2	37
10	2.9	91	3	85
11	5.0	83	0	8
12	—	80	—	—
13	3.3	75	1	3
14	—	79	—	—
15	—	74	—	—
16	4.7	77	0	0
17	—	76	—	—
18	—	83	3	55
19	—	86	—	—
20	—	78	—	—
21	1.3	84	6	40
22	1.9	89	5	60
23	1.5	91	2	45
24	1.7	91	9	23
25	—	90	—	—
26	—	72	—	—
27	2.0	78	2	2
31	3.0	78	0	0

[1] When weather conditions appeared unsuitable for flight, no flight or wind-velocity records were made. No wind-velocity records were made on May 18.

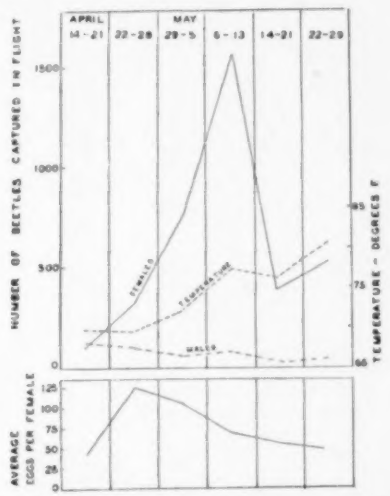

FIG. 1.—Relation of air temperature and seasonal incidence to the number of sugar-beet wireworm adults collected in flight and the average maximum egg production per female. Parma, Idaho, and Adrian, Ore., 1938–41.

Table 2.—Number of sugar-beet wireworm adults collected in flight during different periods, together with air temperatures and egg production. Parma, Idaho, and Adrian, Ore., 1938–41.

Collection Period	Average Maximum Temp. °F.	Number of Beetles	Percentage of Females	Average Number of Eggs per Female
1938				
April 14–21	70.0	0	—	—
April 22–28	69.4	0	—	—
April 29–May 5	65.3	21	100.0	85.7
May 6–13	72.6	271	92.6	35.7
May 14–21	71.6	161	93.8	41.2
May 22–29	80.7	337	95.0	37.0
Total	—	790	94.1	38.8
1939				
April 14–21	75.6	40	17.5	53.9
April 22–28	76.4	74	94.6	166.8
April 29–May 5	79.4	293	92.8	100.4
May 6–13	80.4	596	95.8	70.4
May 14–21	80.2	93	97.8	59.0
May 22–29	78.4	0	—	—
Total	—	1,096	92.2	84.0
1940				
April 14–21	69.5	181	47.0	40.6
April 22–28	67.6	141	74.5	35.2
April 29–May 5	70.3	343	86.6	102.9
May 6–13	80.0	681	95.3	83.8
May 14–21	79.6	105	91.4	78.7
May 22–29	84.0	148	87.8	74.3
Total	—	1,599	85.8	80.4
1941				
April 14–21	63.0	0	—	—
April 22–28	75.7	195	67.7	146.0
April 29–May 5	72.3	158	96.2	108.8
May 6–13	75.1	103	95.1	68.8
May 14–21	71.8	46	93.5	46.5
May 22–25	87.8	86	93.0	42.5
Total	—	588	85.9	95.0
1938–41				
April 14–21	69.5	221	41.6	41.6
April 22–28	69.1	410	74.9	127.5
April 29–May 5	71.8	815	92.3	106.7
May 6–13	77.0	1,651	95.1	69.0
May 14–21	75.8	405	94.1	55.8
May 22–29	80.6	571	92.8	47.0
Total	—	4,073	89.1	74.9

great amount of flight activity was noted over fields containing little or no vegetation, although several infested fields of this type were closely watched. However, some early-season flight by both males and females was noted in certain bare fields. The flights occurred in the afternoons, for the most part between 2 and 4 o'clock, and the largest flights took place on warm, still days when maximum shade temperatures were 70° F. or above. It was observed that the beetles began flight preferably at moments of dead calm or at wind velocities of 1 to 3 miles per hour. For this reason the flights appeared to come in waves corresponding to lulls in the breeze. During the progress of one of these waves there would be a number of beetles flying and a dozen or more could be taken in rapid succession. Then suddenly the flight would stop, and for a time no beetles would be seen. Flights took place in all directions, both with and against the breeze. The stronger the breeze, however, the greater was the tendency for the beetles to be carried with it. So far as could be determined, the beetles were not attracted toward any particular crops or other vegetation, but they seemed rather to fly indiscriminately.

Although it would seem logical to expect a gradual decline in the number of eggs produced per female from the beginning to the end of the flight, females captured during the period April 22 to 28 were carrying more eggs than were females taken during the preceding week. Possibly this is due to the fact that females which came out early in the season often found conditions unfavorable for flight and hence deposited most of their eggs before engaging in flight, whereas females emerging during the latter part of April found weather conditions favorable for flight and hence flew while still gravid. Some of them probably flew before depositing any of their eggs. Thirty-eight females taken in flight on April 25, 1941, laid on an average 200 eggs each, whereas the average for females kept in the laboratory (or under observation) in 1941 was approximately 180 eggs (Table 3). Two females captured in flight in 1941 laid 402 and 409 eggs, these being the highest egg records observed from any females during the 4-year period represented. The average egg production of females collected in flight was compared with that of females dug from soil prior to spring emergence. A summary of these records for the seasons 1939–41 is presented in table 3. Flight-collected females laid from 0.41 to 0.68 as many eggs as females collected from the soil, an indication that

the flight-collected females laid from 32 to 59 per cent of their eggs prior to capture in flight.

To determine whether any of the females flew prior to mating, males were placed in the cans with females selected at random from those caught in flight and were left there until egg counts were made. It was thought that this test would give a valid indication of whether the female was already mated, because, first, a virgin female lays no eggs, or only a few infertile eggs, and, second, placing a male and female in a can with moist soil has in the majority of trials resulted in fertilization of the female and production of a normal quota of eggs. It is concluded from the data in table 4 that a great majority of the females must have been fertilized before flight, inasmuch as placing males and females together did not result in significantly more eggs.

Table 3.—Comparative egg production of sugar-beet wireworm females collected in flight and females collected from the soil prior to emergence. Parma, Idaho, and Adrian, Ore., 1939–41.

Year	Number of Females Collected		Number of Eggs Produced per Female Collected		Ratio of Egg Production of Females Collected in Flight to Those Collected in Soil
	In Flight	In Soil Prior to Emergence	In Flight	In Soil Prior to Emergence	
1939	976	30	87.0	212.8	0.41
1940	1,372	79	80.4	119.3	0.68
1941	505	44	95.0	180.0	0.53

Table 4.—Egg production of sugar-beet wireworm females collected in flight as influenced by the presence of males while in captivity. Parma, Idaho, 1939–41.

Date of Collection	Number of Eggs Produced by Ten Females	
	With Males	Without males
1939		
April 26	1,558	1,389
April 30	1,761	1,535
May 1	1,710	1,852
May 2	412	332
May 2	1,157	946
1940		
April 19	634	455
April 24	752	665
April 24	399	363
May 5	1,079	1,487
1941		
April 22	849	953
April 24	1,277	1,327
April 25	1,856	2,266
April 28	1,759	1,162
April 29	1,431	1,536
April 30	618	908
May 2	1,379	1,169
Total	18,631	18,345

SUMMARY.—Collections of adults of the sugar-beet wireworm were made over a 4-year period by use of standard insect nets. The flight period in southwestern Idaho extends from the middle of April until the end of May. Of the beetles taken in flight for the period 1938–41 about 89.1 per cent were females, while of those swept from vegetation in 1940 about 87.2 per cent were males. Field counts made before spring emergence showed that the sexes occur in about equal numbers. The females taken on the wing subsequently deposited on an average 74.9 eggs each. The great majority of females mated prior to engaging in flight, but some apparently flew before depositing any of their eggs. Flights occurred on warm, calm days and principally between 2 and 4 p.m. —1-6-42.

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Histological Effects of Pyrethrum and an Activator on the Central Nervous System of the Housefly

ALBERT HARTZELL, and HARVEY I. SCUDDER, *Boyce Thompson Institute for Plant Research, Inc., Yonkers, N. Y.*

Krüger (1931) noted morphological changes in the hypodermis, muscles, and nerves of *Corethra* larvae that had been treated with suspensions of pyrethrum flowers in water. The ventral nerve ganglia of treated larvae showed vacuoles that were not present in untreated larvae.

The presence of nerve lesions in meal worm larvae, *Tenebrio molitor* L., and adult grasshoppers, *Melanoplus femur-rubrum* De Geer, that had been killed by pyrethrum concentrates has been reported in previous publications (Hartzell 1934; Hartzell & Wilcoxon 1933, 1934; Wilcoxon & Hartzell 1933). Pyrethrum extracts were applied externally and histological preparations were made following a technique used in the detection of paralysis in man which involves the use of toluidine blue. Lesions were found throughout the main parts of the central nervous system, in the brain, suboesophageal ganglion, the thoracic ganglia, the abdominal ganglia, and the connectives in the above named species. From a study of the histopathology of nerve tissue of insects killed by pyrethrum it was concluded that death is caused by the destruction of the cells of the central nervous system followed by paralysis. Lesions similar to those produced by pyrethrum were found also in the ventral nerve ganglia of meal worms killed by external applications of triorthocresyl phosphate and of organic thiocyanates. No destruction of nerve tissue comparable with that caused by pyrethrum was found in insects killed by rotenone. External applications of mixtures of pyrethrum extract and Sudan III were made at points far removed from spiracles or other body openings. An examination of sections cut with the freezing microtome indicate that pyrethrum penetrates the integument of insects through the trichogen or hair cells and thus is able to reach the nerve endings.

Klinger (1935) made a histological study of the nerve lesions of gypsy moth larvae, *Porthetria dispar* L., after application for 24 hours of a 15 per cent pyrethrum extract. He reports that the nerves appeared to be isolated and surrounded by spaces as contrasted with the check where the tissue was not distorted. A similar histological change was reported for moribund insects. Unfortunately he does not give histological methods except to state that Sudan III, eosin, and toluidine blue were used as stains. Klinger also demonstrated a measurable reduction in the flow of nerve impulse by means of a galvanometer and furnished direct proof that the action of pyrethrum extends to the nervous system in insects. The flow in a pyrethrum injured nerve was about one-fifth that of a normal nerve. Measurements of nerve impulse of insects treated with rotenone were negative.

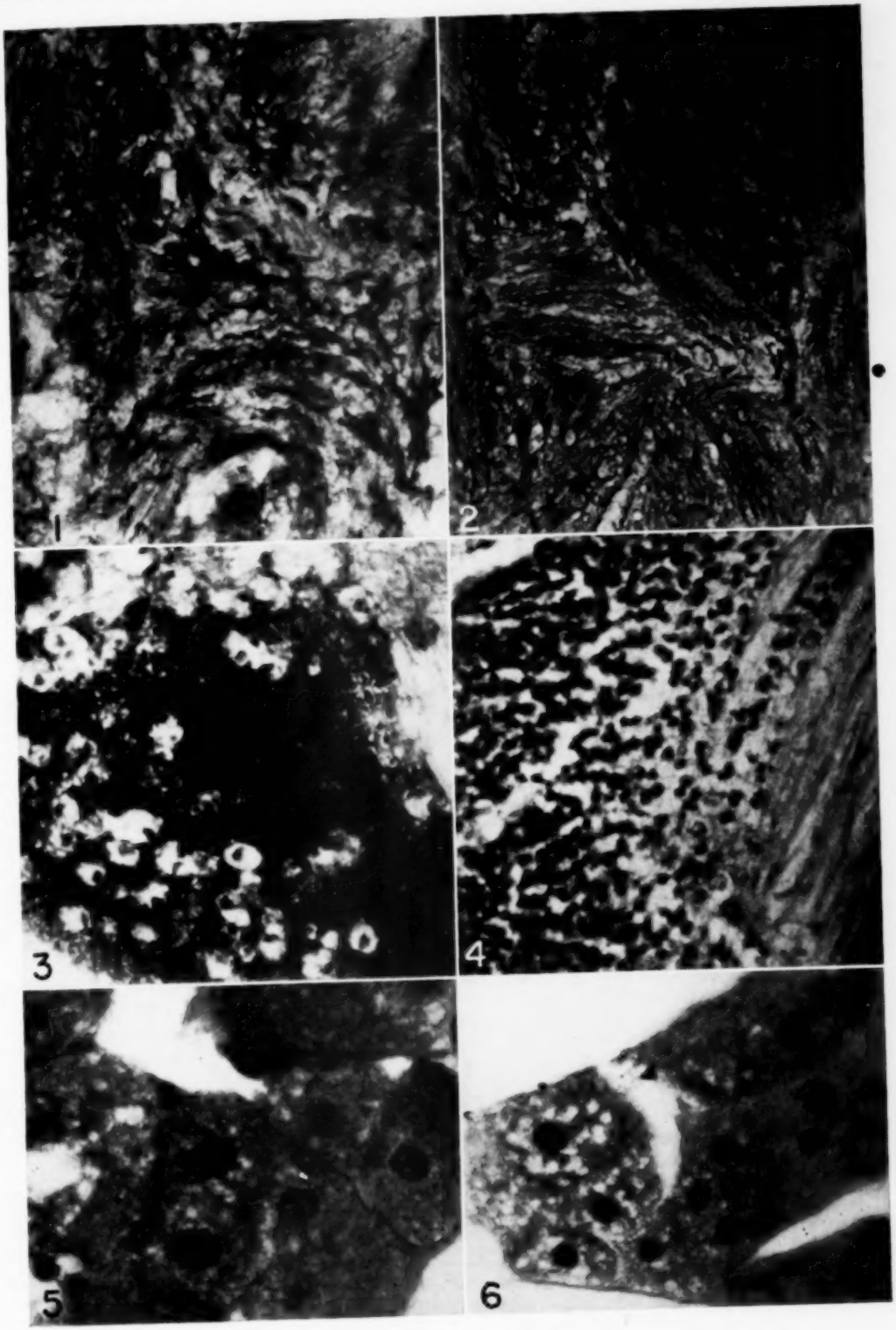
In mosquito larvae killed by petroleum oils, Richards (1941) has demonstrated that asphyxiation produces chromatin clumping in the nuclei of *Culex* larvae, especially nuclei of the central nervous system. He believes that this clumping is not the cause of death but is a criterion of asphyxiation.

In the present investigation a study was made of the histological effects of certain contact poisons on the adult housefly, *Musca domestica* L., with particular respect to the histopathology of the central nervous system and of the closely associated fat and muscle tissues. Under regular Peet-Grady test conditions, the standard five-day adults were treated with pyrethrum, with a pyrethrum activator (isobutyl undecylene amide), and with *Pyrin*,[1] a combination of the activator and pyrethrum. Checks were examined as a study of the normal histology.

The tests were made with 0.1 per cent pyrethrum in *Deobase*, 1 per cent activator in *Deobase*, and 1 per cent *Pyrin* in *Deobase* (0.6 per cent isobutyl undecylene

[1] A product of John Powell & Company, Inc., New York, N. Y.

FIG. 1.—(1) Vertical section through the brain of the housefly, showing the corpus centrale (upper right) and the fiber tracts laterad of it. This figure shows the effect of pyrethrum on the fibers. (2) As in the preceding figure, but untreated. It shows the normal fibers. (3) Vertical section through the anterior ganglionic mass of the compound eye, showing the effect of pyrethrum on the nuclei. (4) Normal section of the anterior ganglionic mass. (5) Normal fat cells from the same region as those of (6). (6) Fat body of the head showing the chromatin clumping and clear layer inside the nuclear membrane as a result of pyrethrum treatment.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amide with 0.04 per cent pyrethrins). The flies selected were among those still down after four hours, at which time the flies had shown nearly complete segregation into two groups, the revivals, and those moribund or dead. We have used the term moribund to indicate a condition of complete inability of the fly to move voluntarily. Flies were chosen that would still elicit some very minor response upon repeated stimulation with a camel hair brush. Extreme caution was exercised to

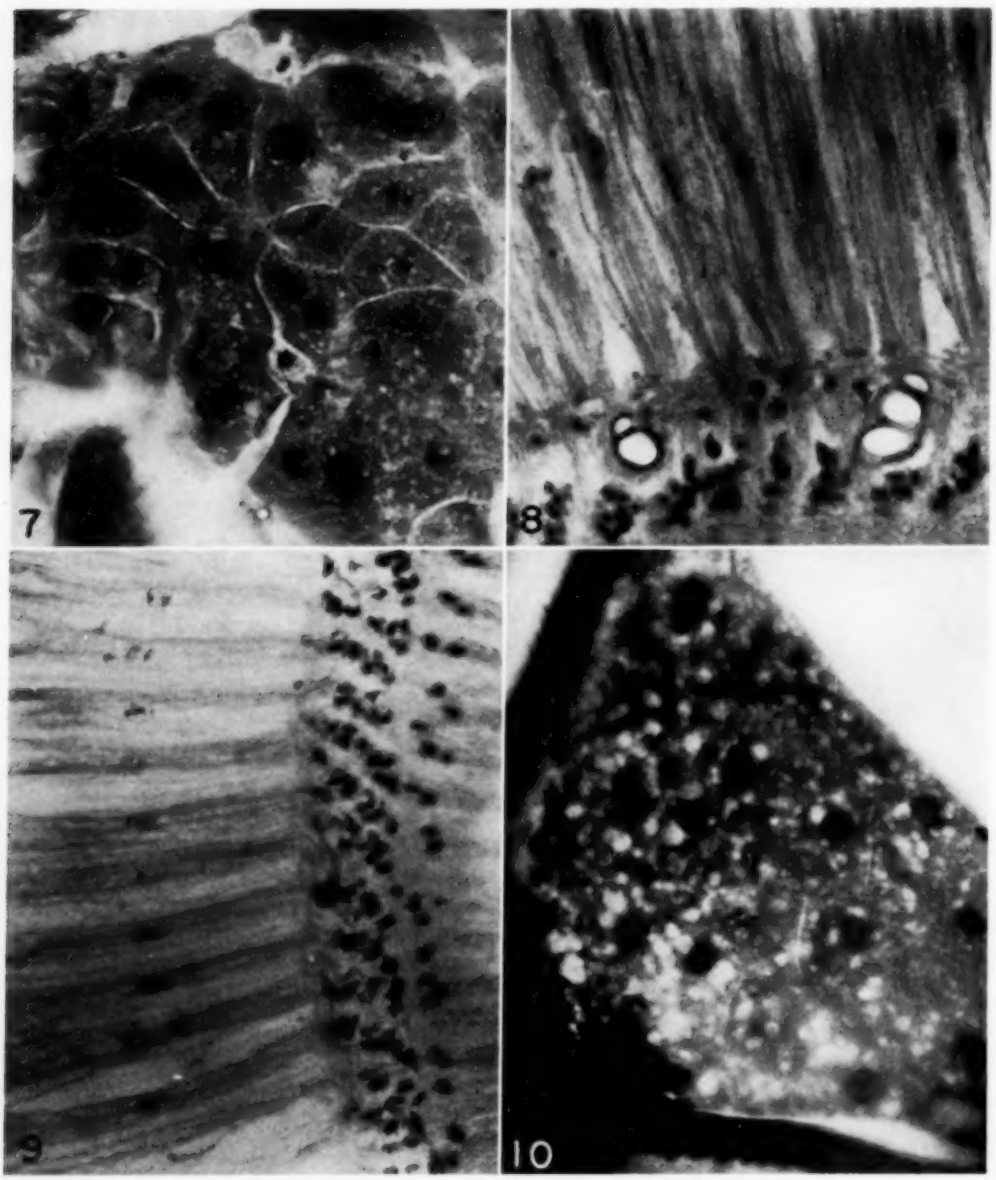

FIG. 2.—(7) Fat body of the head showing the nice chromatolysis caused by the activator (isobutyl undecylene amide). (8) Normal section of the compound eye showing the rhabdosomes (pulled away from the basement membrane at the upper part of the figure) and the postretinal fiber layer which is in turn underlaid by the palisade cell layer visible in the figure in the lower third. (9) Section of the compound eye showing the distorted angular nuclei of the cells that have invaded the postretinal fiber layer. The nuclei of the rhabdosomes above show marked chromatolysis. The pathology is that of the activator. (10) Fat body of the head showing the effect of *Pyrin*. The nuclei are very similar to those in figure 7 that show effects of activator alone.

prevent the inclusion of dead flies, so that the histological pictures here considered are those brought about by the insecticide, supposedly uncomplicated by post mortem degenerative changes.

The moribund flies were killed in fixing fluids warmed to 70° C., namely Bouin's, Dietrich's, and Gilson's. They were then dehydrated by the n-butyl alcohol technique and imbedded in 60–62° paraffin. The sections were cut at 7μ and stained with iron haematoxylin and erythrosin. For specific study of the fiber tracts of the brain, the sections were stained with the silver albumose and gold chloride method of Bodian (1937).

All of the flies considered in this preliminary report were males, for the reason that their resistance to the tests was very low compared to that of the females, and consequently they represented the majority of the moribund individuals. Therefore it was decided that only males be used in this preliminary work.

The histopathology of a pyrethrum-treated fly in the moribund stage shows a general nuclear picture that occurs in all of the body tissues. Every nucleus seems to be affected by a marked clumping of the chromatin, which tends to leave a clear peripheral area just inside the nuclear membrane. This clumping appears as an aggregate of chromatin masses that individually look like chromosomes.

The foremost effect of pyrethrum to be expected was shown by the Bodian technique to consist of drastic destruction of the fiber tracts of the brain. Figure 1-1 shows the pathological condition and figure 1-2 shows the normal histology. The wholesale disorganization is apparently due to actual dissolution of the fibers. Large, irregularly staining fiber remnants can be seen as wavy dark lines.

Between the first and second synaptic plates of the compound eye system there is a great anterior group of neurocytes that are particularly conspicuous because of the dense mass of their nuclei. This structure is known as the anterior ganglionic mass. Treatment of the fly with pyrethrum produces a marked clumping as shown in figure 1-3 (cf. normal histology in figure 1-4) in which pronounced peripheral spaces have formed about the chromatin clumps. With further damage the nuclear membrane is undoubtedly broken.

Pyrethrum also affects the thoracic compound ganglion, causing the characteristic peripheral nuclear vacuoles. Its effect on the retina of the eye is of the same character, the nuclei of the rhabdosomes showing the vacuoles prominently, surrounding the central clump of chromatin. (See figure 3-11 and cf. with the normal in figure 2-8.) Pyrethrum does not seem to affect the postretinal fiber layer as does the activator (Fig. 2-9).

The effect of pyrethrum on the muscle fibers is rather prominent for a pair of muscles that run from the occiput to the base of the proboscis and pass on either side of the caudal part of the brain. In these muscles (Fig. 3-15) the nuclei present the usual picture of clumping into rod-like or oblong dense masses, but the added feature is the literal fenestration of the cytoplasm by vacuoles. One general effect on muscle seems to be a loss of the sharp stainability of the striations. A comparison of the fenestrated muscle in figure 3-15 with the normal tissue in figure 3-14 makes one realize why there is loss of locomotor faculties in a treated fly.

The fat cells of the head are closely associated with the brain and are particularly good indicators of histopathology. Pyrethrum causes the clumping observed elsewhere and also there appears to be a separation of the cells in the fat body, probably because of cytoplasmic shrinkage (figure 1-5 pathological, figure 1-6 normal histology).

Many other parts of the body show pyrethrum effects. Most notable of these are the labial (salivary) glands, Malpighian tubules and alimentary canal epithelium.

Isobutyl undecylene amide, the activator in *Pyrin*, shows a very interesting group of effects that contrast with those produced by pyrethrum. This activator seems to cause chromatolysis, as opposed to the clumping action of pyrethrum. This is best seen in the altered histology of the fat cell nuclei (Fig. 2-7). The chromatin is usually persistent on the condensed linin fibers, but the nucleus in general appears partly or wholly "washed out." In some instances this may create the effect of a highly vacuolate, angular-margined mass of chromatin. It does not show any peripheral clear area such as accompanies the shrinkage and clumping in the pyrethrum picture.

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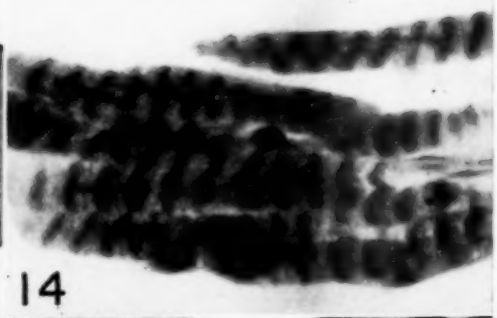
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The activator shows about the same effect on muscle as does pyrethrum, but it does not alter the stainability of the striations, and further, it exhibits the vacuolate rather than the clumped chromatin. The same muscle that was shown for pyrethrum is shown in figure 3-16 portraying the effect of the activator. The contrast is fairly evident.

The postretinal fiber layer of the optic apparatus shows a peculiar activator effect (Fig. 2-9), in that the region of the tracheae (the tapetum) is heavily invaded by cells that show the characteristic angular nuclear margins of the activator picture. The close association of these cells with the numerous tracheae of the tapetal layer would suggest that perhaps the local effect was caused by penetration of the activator by way of these tracheae.[1]

Pyrin, from the point of view of histological effects, combines the effects of both pyrethrum and activator, its constituents. The histopathology shows muscle lesions similar to those of pyrethrum, even to the clumping of the chromatin (Fig. 3-13). On the other hand the fat cells around the brain show the activator picture quite completely (Fig. 2-10), the nucleus having the definite signs of chromatolysis. The anterior ganglionic mass shows for *Pyrin* a gross breakdown in structure that surpasses even that shown by pyrethrum (Fig. 3-12). There is the same clumping and large peripheral spaces that pyrethrum produces, but the mass seems far more homogeneous and chromatin breakdown appears to be more complete.

SUMMARY AND CONCLUSIONS—Pyrethrum and its activator, isobutyl undecylene amide, each was found to show rather distinct and characteristic effects upon the central nervous system and associated tissues of the adult housefly.

Pyrethrum has a widespread clumping effect on the chromatin of the nuclei, while the activator seems to cause a chromatolysis or dissolution of the chromatin.

A combination of these two agents (as in *Pyrin*) shows a histological picture that is a summation of the effects of both. The interaction of these two types of nuclear destruction may be the true basis of "activation."

It seems very likely that a study of the progression of these effects can be made, perhaps even to include the nature of revival of knockdowns.—12-17-41.

[1] V. B. Wigglesworth has recently demonstrated that with *Cimax* paralyzed with pyrethrum, the spiracles are closed and still react to CO_2. He concludes that dessication cannot therefore be the main cause of death with pyrethrum poisoning and confirms the destructive action of pyrethrum on the central nervous system. (Proc. R. Soc. London A 16 pt. 1–3: 11–14. 1941.)

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FIG. 3. (×700)—(11) Section of the retinal layer of the compound eye as affected by pyrethrum. There are prominent vacuoles around the chromatin masses of the rhabdosome nuclei (at bottom of figure). Likewise, there are such vacuolate areas distally in the region of the pigment cell nuclei. The nuclear membrane is most certainly broken down under such conditions. (12) Severe changes in the nuclei of the anterior ganglionic mass as shown in section of the compound eye system. The vacuolation and the obliteration of individual nuclei is all a result of *Pyrin* treatment. (13) Muscle of the head showing fenestration due to *Pyrin*. This figure shows an appearance similar to that of the same muscle in a fly treated with pyrethrum alone, as in figure 15. (14) Normal muscle from the same region of the head as in figures 13, 15, and 16. (15) Muscle of the head showing the very characteristic pyrethrum picture. (16) Muscle as in the preceding figures, but showing the effect of the activator in the different character of the nuclei.

Insect Food Caches as Reservoirs and Original Sources of Some Stored Products Pests

E. Gorton Linsley, *University of California, Berkeley*

Stored products pests (and certain other household insects) are not uncommon in the nests of bees and wasps. Unfortunately, however, most observers have apparently regarded them as unimportant and have either failed to record their occurrence or have noted them only in passing. The honey bee, of course, is an exception because the presence of pests in the hive has some economic significance. However, even in apicultural literature published data are inadequate, the more typical pests of stored products having been commonly confused with certain other inhabitants of the hive, especially wax moths.

In the spring of 1941, in connection with another study, Mr. J. W. MacSwain and the writer examined eight nesting sites of *Anthophora* (five species) in seven localities in central and southern California. Dermestids of several types were abundant in all of the sites, the California spider beetle, *Ptinus californicus* and the confused flour beetle, *Tribolium confusum*, were present in three, the Indian meal moth, *Plodia interpunctella*, the drugstore beetle, *Stegobium paniceum*, and the black flour beetle, *Aphanotus parallelus*, in two, and the saw-toothed grain beetle, *Oryzaephilus surinamensis*, and the webbing clothes moth, *Tineola biselliella*, each in one site. In a single colony on the edge of the Mojave Desert approximately ten miles from the nearest human habitation, the drugstore beetle, the saw-toothed grain beetle and one of the so-called cabinet beetles, *Trogoderma ?ajax*, were found, and in a second area, only slightly less isolated, the Indian meal moth and the webbing clothes moth were both present.

Of these insects *Ptinus californicus* is a native species which seems to be definitely associated with bees, having never been recorded as breeding outside of bees' nests. It is most common as a pollen feeder in cells of *Osmia*, especially where nesting sites are re-used year after year. However, when brought into the laboratory it can be readily reared on cornmeal and other cereal products. *Trogoderma ?ajax* and *Aphanotus parallelus* are also native species. The former is the commonest dermestid associated with anthophorid bees in California and has been found infesting grain (probably as a secondary invader feeding partially on exuviae and detritus of some other insect). The latter species is a common pest of many stored products, especially dog biscuits, rabbit food, and various cereal products. Of the remaining species, *Plodia interpunctella*, *Stegobium paniceum* and *Oryzaephilus surinamensis* live on a wide variety of plant products, apparently finding the pollen stored by bees one of many suitable foods. *Tineola biselliella* probably lives solely as a scavenger on products of animal origin. Probably none of these last species is native to California, yet their presence even in isolated habitats, suggests that they find the environment of bees' nests satisfactory and may possibly have occupied it for a long period of time.

Among the stored products insects and their relatives which occur in nests of bees and wasps, the following may be noted:

Coleoptera: Dermestidae.—As might be expected, dermestids are common inhabitants of nests of both bees and wasps. Unfortunately, little attention has been given to the exact identification of the species involved. Hicks (1926), Mickel (1928) and numerous other authors have referred to the abundance of *Anthrenus* spp. in nests of *Anthophora*, *Osmia*, and certain other bees. The varied carpet beetle, *Anthrenus verbasci* (L.), and the buffalo carpet beetle, *A. scrophulariae* (L)., have both been recorded from bees' nests but the determinations may be open to scrutiny. *Anthrenus* (*Helocerus*) *fuscus* Latr., according to Maréchal (1932) breeds in the nests of *Osmia* in Europe. In California at least two species of *Anthrenus*, an *Attagenus* (*?piceus* Oliv.) and a *Trogoderma* (*?ajax* Csy.) have been found in the nests of *Anthophora* and *Osmia* (Linsley & MacSwain, 1941). *Trogoderma glabrum* Herbst also breeds in the nests of *Osmia* and *Odynerus* (Maréchal, 1932) and the common *T. ornatum* Say

has been recorded from honeycomb (Chittenden 1897; Patton 1931) and from the nests of spiders (Auten, 1925). Probably all of these species are primarily scavengers on animal materials (insect parts, etc.) but there is some evidence to suggest that *Trogoderma* larvae feed on stored pollen. The pollen-feeding habit in adult *Anthrenus*, *Attagenus*, and *Trogoderma* is well known.

Riley (1870), Lintner (1890) and Bartels (1915) have noted the feeding of the larder beetle, *Dermestes lardarius* (Linn.), in combs of the honeybee and Milum (1940) discusses dermestids feeding on brood combs containing pollen, dead larvae or bees but does not specify the species involved.

CUCUJIDAE.—At least two cosmopolitan stored products pests in this family occur in nests of bees or wasps. The sawtoothed grain beetle has been found by J. W. MacSwain and the writer in *Anthophora* cells in California and the rust-red grain beetle, *Laemophloeus ferrugineus* (Steph.) by Tuck (1897) in the nests of *Vespa* in England. Their exact status as nest inhabitants has not yet been determined but probably both species feed on pollen and detritus, the latter probably also on insect remains.

CRYPTOPHAGIDAE.—Members of three genera of Cryptophagids have been found in nests of bees or wasps. In the genus *Cryptophagus*, 19 species have been recorded from dwellings, warehouses, cellars, bakeries, mills, or granaries. Nine of these were found by Tuck (1896–97) living with social bees and wasps in Britain. *C. badius* Sturm occurred with *Vespa crabro L.*; *C. pubescens* Sturm, *C. pilosus* Gyll., and *C. distinguendus* Sturm with one or more species of *Vespula*, *C. punctipennis* Bris., *C. umbratus* Erh. and *C. sapinatus* Sturm with *Bombus;* and *C. scanicus* (Linn.) and *C. setulosus* Sturm with both *Vespula* and *Bombus*. The last has also been found in bumblebee nests by Sladen (1912). Frison (1926) has recorded still another species, *C. croceus* Zimm., from *Bombus* nests in Illinois according to Donisthorpe (1927) *C. loevendali* Ganglb. lives in wasp nests in trees and *C. pubescens* Sturm in nests in the ground.

The food habits of *Cryptophagus* have not been well understood but Hinton & Stephens (1914) have reared *C. acutangularis* Gyll. on a wide variety of fungi and found that the species would thrive on a diet of *Penicillium* conidia. This species was also found to be capable of mechanical, internal and external transportation of fungi. It is highly probable, therefore, that in nests of Aculeate Hymenoptera as well as in stored food products, *Cryptophagus* spp. feed on fungi and molds rather than on the food products themselves.

Atomaria ruficornis Marsh. and *A. peltata* Kraatz were found by Tuck (1896) in *Vespa* nests. *Antherophagus pallens* (Fab.) and *A. nigricornis* (Fab.) are well-known inhabitants of bumblebees' nests in Europe (Tuck 1896; Sladen 1912; Scott 1920, *et al.*) and *A. ochraceus* Melsh. is common in similar situations in eastern United States (Plath 1934).

LATHRIDIIDAE.—Many lathridiids occur regularly in nests of bees, wasps, and ants. Among the stored food products pests may be mentioned *Cononimus constrictus* (Gyll.) from nests of *Lasius* ants (Walker 1920), *C. nodifer* (Westw.) from those of bumblebees (Frison 1926) and *Dolichovespula* (Donisthorpe 1917) and *Enicmus minutus* (Linn.) from both bumblebees and wasps (Morley 1899).

TENEBRIONIDAE.—The most common tenebrionid inhabitants of bees' nests are the flour beetles. The rust-red flour beetle, *Tribolium ferrugineum* (Fab.) has been reported by Kotinsky (1907) from nests of *Megachile* in Hawaii and the confused flour beetle has been found in cells of *Anthophora*, *Osmia*, and *Clisodon* in California (Linsley & MacSwain). The black flour beetle, *Aphanotus parallelus* Csy., also occurs in the nests of *Osmia* and *Anthophora*, and the closely related *A. brevicornis* (Lec.) has been recorded from cells of *Xylocopa* by Davidson (1893) and Nininger (1916) and of *Anthidium* by Hicks (1929). In addition, *Cynaeus angustus* (Lec.) has been found in *Osmia* nests in southern California. This latter species has been reported from a flour-mill in Washington (Hatch 1940).

Frison (1926) has recorded two species of mealworms, *Tenebrio obscurus* Fab. and *T. tenebroides* Beauv. from *Bombus* nests in Illinois.

PTINIDAE.—*Ptinus sexpunctatus* Panzer was apparently the first ptinid species taken in association with bees. In 1872, Bedel reported its capture at the nest

entrances of *Megachile muraria* (Retzius). It has since been recorded from the nests of the following bees: *Megachile muraria* (Retzius) Bedel 1872; Redtenbacher, 1874; *M. willughbiella* (Kirby) Maneval 1929; *Osmia rufa* (Linn.) (Chevalier 1923, Hamm 1924; Maneval 1929, Maréchal 1932); *O. cornuta* (Latr.) (Maréchal 1932); *O. emarginata* Lep. (Enslin 1925; Maneval 1929); *O. villosa* (Schenck) (Maneval 1929); *O. mitis* Nylander (Maneval 1929); *Hoplitus adunca* (Panzer) (Maneval 1929); *Chelostoma nigricorne* (Nylander) (Maneval 1929); and *?Bombus* sp. (Fowler 1889).

The well-known white-marked spider beetle, *Ptinus fur* (Linn.), also feeds on pollen in the nests of bees. It has been recorded from *Osmia tridentata* Dufour & Perris by Enslin (1925), *O. rufa* by Schmitt (1929), and *Chelostoma maxillosum* (Linn.) by Maréchal (1932) as well as from the combs of *Apis mellifera* L. (Bartels 1915) and *Vespa crabro* Linn. (Hüsing 1925).

Cros (1932) has given an account of *Ptinus raulogeri* Pic living in the nests of *Osmia longispina* Perez, and Linsley & MacSwain (1941) have discussed the habits of *Ptinus californicus* Pic as a depredator in nests of *Osmia lignaria* (Say) and *Anthophora linsleyi* Timb.

Arnhart (1929) and Brassler (1929) have also called attention to depredations of *Ptinus raptor* Linn. on pollen stores of honeybees in Europe and Rayment (1935) records *Ptinus exulans* Er. from deserted hives in Australia.

The golden spider beetle, *Niptus hololeucus* Fald. is listed by Tuck (1897) as one of the inhabitants of nests of *Dolichovespula*.

ANOBIIDAE.—Linsley & MacSwain (1941) have noted the occurrence of the drugstore beetle, *Stegobium paniceum* (L.) as a pollen feeder in the nests of *Anthophora linsleyi* Timb. in southern California. Rayment (1935) states that the tobacco beetle, *Lasioderma serricorne* (L.) lives in the cells of *Anthophorae* in Australia but his figures[1] are of the drugstore beetle, a much more likely nest inhabitant.

LEPIDOPTERA: PHYCITIDAE.—The Indian meal moth is a common occupant of bees' nests. It has long been known as a pest of hives and stored frames (Fletcher 1889; Dunham 1929; Milum 1940b; *et al.*) and has also been reported from nests of *Bombus* (Frison 1926) and *Anthophora* and *Osmia* (Linsley & MacSwain).

The Mediterranean flour moth, *Ephestia kuehniella* Zell., has been recorded from similar habitats. Johnson (1895), Gillette (1898), Milum (1940b), Essig (1940) and numerous other authors have recorded it from combs of the honeybee; Davidson (1894), Johnson (1895) and Chittenden (1900) from *Bombus*, and other writers from *Vespa* and *Vespula*. The fig moth, *E. cautella* Walk., and the chocolate moth, *E. elutella* Hbn., have also been reported from combs of the honeybee by Milum (1940) and Laboulbéne (1864) respectively.

The dried fruit moth, *Vitula serratilineella* Rag., has been found in weak colonies of bees (Cockle 1920; Essig 1926) and the closely related *V. edmandsii* (Pack.) is a common inhabitant of nests of bumble bees in eastern United States (Frison, 1926; Plath, 1934, *et al.*) and has been reported from combs of the honeybee in Colorado and Nebraska (Anon, 1932; Milum, 1940b).

GALLERIIDAE.—The wax moth, *Galleria mellonella* (L.), and the lesser wax moth, *Achroia grisella* (Fab.), are well-known occupants of the hive where they feed as scavengers on brood combs, frass, pollen, etc. According to Meyrick (1895) the latter also eats dried apples, to which Forbes (1923) adds raisins, crude sugar and dried insects and Gotze (1929), seeds of many kinds. The bumblebee moth, *Aphomia sociella* (L.) is a common pest of bumblebees' nests in Europe and has been reported from combs of the honeybee (Suire, 1932). A related species, *A. gularis* Zeller, feeds on many kinds of stored products including cereals, nuts, and dried fruits (Richards, 1931).

PYRAUSTIDAE.—According to C. Heinrich (in litt.), *Chalcoela iphitalis* (Walker) and *Dicymolomia pegasalis* (Walker) feed on wax (and perhaps other materials) in bee and wasp nests.

TINEIDAE.—The webbing clothes moth, *Tineola biselliella* Hummel, has been found in the cells of *Anthophora* in southern California (Linsley & MacSwain 1941). This species feeds almost exclusively on animal products, probably living in bees' nests as a scavenger on insect remains.

[1] Pl. 45, figs. 19, 21.

PSOCOPTERA: ATROPIDAE.—The cereal psocid, *Troctes divinitorius* Müller, and perhaps other related species have been found feeding on pollen in bees' nests in southern California.

ACARINA.—Several species of mites also occur in nests of bees and wasps. The identifications of the species involved are doubtful and hence their status in relation to stored products pests cannot be determined.

DISCUSSION.—The majority of our stored products pests appear to have been derived from one or more of the following natural sources: (1) Seed infesting species which infest similar material in nature, (2) scavengers feeding generally on dead plant or animal products, (3) scavengers or semi-predators living primarily under bark, or (4) scavengers or depredators inhabiting the nests of bees, wasps, and other Aculeate Hymenoptera.[1] The first group comprises the weevils, bruchids, and similar insects. The second includes most of the moths and dermestids and some of the ptinids and anobiids. Group three is made up largely of beetles, especially the families Tenebrionidae (*Tribolium*, *Aphanotus*, *Gnathocerus* etc.), Cucujidae (*Laemophloeus*, etc.) and Ostomatidae (*Tenebroides*). The fourth group includes, in addition to a few characteristic elements of its own, some species that also occur in groups two and three.

Perhaps the most significant members of groups of stored products pests that inhabit nests of Hymenoptera are the Ptinidae. At least three species, *Ptinus sexpunctatus*, *Pt. vaulogeri*, and *Pt. californicus* appear to live regularly in bees' nests, *Pt. fur* has been found in nests of both solitary and social bees and wasps, and *Pt. raptor*, *Pt. exulans*, and *Niptus hololeucus* occur at least occasionally in hives. It is very probable that bees' nests provide the natural habitat of at least the first three (possibly also the fourth) of these species.

Probably the only other beetles mentioned above that live primarily in the nests of bees are members of the cryptophagid genus *Antherophagus*. The remaining beetles (dermestids, cucujids, tenebrionids, anobiids) very likely find this habitat one of many favorable to their development. However, bee and wasp nests may well serve as reservoirs for some of these species. In the case of the saw-toothed and rust-red grain beetles, the red and black flour beetles and the drugstore beetle these reservoirs might occasionally prove of some importance. The maintenance of large numbers of small, widely scattered populations in nature assures foci for future infestations of man's stored foods.

The moths fall mostly in the category with the last mentioned group of beetles. Exceptions occur in the case of the lesser wax moth and the bumblebee moth (possibly also *Vitula*) which, like the species of ptinids recorded above are primarily bees' nest insects.

Psocids and mites, although common in nests of Aculeate Hymenoptera, are not sufficiently well known to permit an interpretation of their relationship to stored products pests.

Apparently gregarious bees (especially anthophorids), associates of gregarious bees (especially *Osmia*), and the social bees (*Apis*, *Bombus*) and wasps (*Vespa*, *Vespula*, *Dolichovespula*) provide more favorable conditions for the maintenance of stored food inhabiting insects than other groups of bees and wasps. This is undoubtedly due to the fact that such species use their nesting sites for longer periods of time and develop larger and more concentrated populations and stores of food than do the more solitary forms.

CONCLUSIONS.—From the evidence at hand it would appear that a large percentage of stored products pests occur in the food caches of bees and wasps.

For many of these insects, nests of bees and wasps appear to provide a natural habitat, and for at least a few, a possible original source.

The nests of bees and wasps may serve as reservoirs for certain stored products pests, maintaining small populations which may later serve as foci for infestations of foods stored by man.—1-6-42.

[1] An important habitat which should be examined in the light of the present problem is the burrows and nests of rodents and other animals. These may well have been concerned in the evolution of food habits involving the transition from plant and animal products in the open to more concentrated stores in protected, more uniform environments.

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Experiments with Poisoned Bait to Control Armyworms in Wheat

R. G. DAHMS, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine and Oklahoma Agricultural Experiment Station*, and F. A. FENTON, *Oklahoma Agricultural Experiment Station*

The armyworm, *Cirphis unipuncta* (Haw.), is often a serious pest in wheat in Oklahoma. The control of this insect by the use of poisoned-bran bait has been effective, but the quantity of bait to use per acre and the optimum concentration of poison in the bait have not been definitely determined. A severe outbreak of this insect in Oklahoma in the spring of 1941 afforded an opportunity to study these factors in armyworm control.

The experiments reported in this paper were performed on 6 acres of wheat on the Washita River Bottom near Chickasha, Okla. The wheat was badly lodged and had previously carried a heavy infestation of leaf rust, *Puccinia triticina* Erik. However, at the time these experiments were started the rust and armyworms had destroyed all the leaves and most of the awns. The worms on the experimental plots averaged 105 per square yard, and most of them were in the last instar. The wheat at the beginning of the trials was in the early milk stage. During these experiments cloudiness prevailed and several light-to-heavy thundershowers occurred. The plots were 150 feet by 72.5 feet, or 0.25 acre. The baits were mixed in the mornings and applied by hand between 4:00 and 6:00 p.m. the same day. The poison was sodium arsenite, containing 32 per cent of arsenious oxide (4 pounds of arsenious oxide per gallon), which was used at the rate of 2 quarts per 100 pounds of wheat bran. Sufficient water was added to the mixture so that when it was tightly squeezed by hand a little would ooze out between the fingers. No molasses or other attractant was used. The finished bait was moist but crumbly and scattered well when broadcast by hand. The percentage of kill was determined by counting the dead worms per 100 found at two points in each plot. Counts were made, when possible, at 15, 40, and 64 hours after the baits were applied, and the highest percentage of kill for any one of the three counts was considered the percentage killed.

AMOUNT OF BAIT PER ACRE.—The bait was spread at the rate of 10, 20, 30, and 40 pounds per acre, dry weight. The percentages of kill at all rates were rather low, but this is thought to have been due to the adverse weather conditions. In one experiment when no rain fell for several hours after the bait was spread, kills of

74.0, 77.0, and 76.5 per cent were obtained for the 20, 30, and 40-pound rates, respectively. The records indicate that 10 pounds of poisoned bait per acre was not enough for effective control, while 20, 30, and 40 pounds gave approximately the same kill.

CONCENTRATION OF SODIUM ARSENITE.—In most experiments using poisoned-bran bait for armyworm control, 2 quarts of sodium arsenite per 100 pounds of bran has been used. To determine whether a smaller proportion of poison would be effective, a bait containing 1.5 quarts of sodium arsenite per 100 pounds of bran was spread at the rate of 20, 30, and 40 pounds per acre. A bait containing 2 quarts of sodium arsenite per 100 pounds of bran was spread at the same time and rates on adjacent plots. The bait containing 2 quarts of sodium arsenite caused considerably better kill at the end of 40 hours than the 1.5 quart concentration, but at the end of 65 hours the kills were about the same for the two concentrations.

INJURY TO WHEAT BY THE ARMYWORM.—To study the value of poisoned bait for reducing injury to the wheat, samples of 100 wheat heads were taken at various locations in the field before the bait was applied and at harvest time, about 3 weeks later, five samples of 20 heads each were taken from each plot. These were graded into the following classes and degrees of injury: No injury (0), part of awns eaten (1), all of awns eaten (2), tips of some kernels eaten (3), tips of all kernels eaten (4), some kernels completely eaten (5), and all kernels eaten (6). The number of heads falling into each class was multiplied by the class number and the products were totaled. This total divided by the total number of heads gave the average index number. An objection to this method of evaluating the injury by the armyworm is that it assumes that no injury is done by the removal of the leaves, which usually takes place before the beards or kernel tips are eaten.

There was an average of 105 worms per square yard when the bait was applied, and most of these worms were in the last instar. Regardless of the treatment, there was no significant difference in the amount of damage caused by the worms, an indication that most of the injury had occurred before the bait was applied. Davis & Satterthwait (1916) found that 80 per cent of the foliage eaten by armyworms is consumed during the last instar. This emphasizes the desirability of killing the worms in the early instars so far as protection to wheat is concerned. Eight worms per square yard did little injury so far as actually eating grain was concerned. Some injury was done to the kernels when the infestation was 42 worms per square yard, whereas an infestation of 105 worms or more did serious damage.

SUMMARY.—Poisoned-bran bait spread at the rate of 10 pounds, dry weight, per acre was not enough for effective control of the armyworm in wheat. Bait spread at the rate of 20, 30, and 40 pounds per acre gave approximately the same kill, an indication that not over 20 pounds per acre need be applied to kill armyworms in wheat. The insects were killed in a shorter time when 2 quarts of sodium arsenite were used per 100 pounds of bran than when 1.5 quarts were used, but at the end of 72 hours the mortality was not significantly greater in the plots that received bait containing 2 quarts of sodium arsenite.

Eight armyworms per square yard did not injure the kernels, but 42 worms, or more, per square yard injured some kernels. The results from these experiments would indicate that bait should be applied when the worms are in the early instars and that, if they are not killed until they are nearly mature, the reduction in injury to the wheat will be rather small.—1-7-42.

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White Grub Control with Dichloroethyl Ether[1]

P. O. Ritcher and H. H. Jewett, *Kentucky Agricultural Experiment Station, Lexington*

Two notes on the use of beta-beta dichloroethyl ether solutions, one on wireworm control by Campbell & Stone and one on sod webworm control by Stone & Elmore, appeared in 1937. Since that time many other papers on the use of dichloroethyl ether as a soil insecticide have been published. Of these, the only paper dealing with scarabaeid larvae was by Hartzell & Wilcoxon (1939). They reported satisfactory control of Japanese beetle larvae with two spray applications, one week apart, by using one gallon per square yard of a saturated aqueous solution of dichloroethyl ether containing 0.1 per cent *Tergitol 7* penetrant.

In 1937, H. H. Jewett began a study of dichloroethyl ether for the control of green June beetle larvae, *Cotinis nitida* L., while in 1938, P. O. Ritcher began a similar study with May beetle grubs belonging mainly to the species *Phyllophaga hirticula* (Knoch). The results of the two investigations are combined in this paper.

Methods.—Tests were made in small plots in fields of Kentucky bluegrass where grub populations were sufficiently dense and in plots stocked with 25 or 50 third instar larvae. The plots were surrounded by metal, screen or board frames or by untreated borders. Because of the migratory habits of green June beetle larvae, all the *Cotinis* plots were enclosed. Plots differed in size but were arranged in series so that each treatment could be replicated either four or five times. Enclosed plots used for *Phyllophaga* tests were either 2 or 3 feet square. Unenclosed plots for tests with *Phyllophaga* were either 5 by 8 or 10 by 10 feet and were separated by untreated borders. The plots used to study green June beetle grub control were 3 feet square. Applications were made with sprinkling cans except for the 10 by 10 field plots where a power sprayer was used.

Examination of the soil was begun five days after treatment. The soil in the enclosed plots was examined to a depth of six inches for *Phyllophaga* grubs and to a depth of ten inches for *Cotinis* grubs. The per cent of kill of *Phyllophaga* grubs was based on the number of dead and live grubs found and for *Cotinis* grubs on the number of living grubs found. Six or more 1/40,000-acre areas were dug in the larger field plots treated to control *Phyllophaga* grubs. In the experiment where a power sprayer was used, as many 1/40,000-acre areas were examined as necessary to yield 25 dead or live grubs. Where check plots were included, the formula of Abbot (1925) was used to calculate the per cent of control.

Amount of Material.—Snapp (1939), Bohart (1940) and Jones (1940) used 1 gallon of dichloroethyl ether solution per square yard, while Hartzell & Wilcoxon (1939) used two 1-gallon treatments applied a week apart. Since preliminary work by the present writers indicated that at least 2 gallons per square yard was needed to wet soil beneath bluegrass sod to a depth of four or five inches, tests were made to compare one- and two-gallon dosages of ether solution for controlling both genera of grubs. Tests with *Cotinis* grubs were made in May, 1940, in plots one yard square; those with *Phyllophaga* grubs were made August 20, 1941, in plots 10 feet square, treated with a power sprayer. The results of these tests indicated that the smaller amount of ether solution was much less effective (Table 1).

Use of *Tergitol 7* Penetrant.—Some workers used solutions of 5, 10, or 20 cc. of dichloroethyl ether in one gallon of water while a few used saturated solutions (37.8 cc. per gallon at 68° F.). Others made emulsions, Pepper (1940), while a few added wetting agents to effect solution and increase killing power. Among the latter were Hartzell & Wilcoxon (1939) who used 0.1 per cent and 0.5 per cent *Tergitol 7* penetrant, a sulphated alcohol, in combination with a saturated solution of dichloroethyl ether. The 0.5 per cent *Tergitol* dosage resulted in slight to severe injury of bluegrass.

In 1941 comparisons were made between the control of white grubs obtained with ether solution containing 32 cc. of ether and 4 cc. of *Tergitol 7* pene-

[1] The investigation reported in this paper is in connection with a project of the Kentucky Agricultural Experiment Station and is published by permission of the Director.

Table 1.—Comparison of 1 and 2 gallons of dichloroethyl ether solution per square yard for grub control in sod.

No.	Treatment per Square Yard		Per Cent Grubs Dead						Mean Per Cent Control
			Replications					Mean	
			1	2	3	4	5		
			Phyllophaga Larvae[1]						
1	Dichloroethyl ether *Tergitol 7* Water	64 cc. 4 cc. 2 gal.	96	68	92.3	84	—	85.1	—
2	Dichloroethyl ether *Tergitol 7* Water	32 cc. 2 cc. 1 gal.	45	24	7.7	12	—	22.2	—
3	Sodium cyanide Water	11.7 gms. 2 gal.	69.2	88.9	96.5	69.2	—	80.9	—
			Cotinis nitida Larvae[2]						
1	Check No treatment		2	2	4	0	0	1.6	—
2	Dichloroethyl ether *Tergitol 7* Water	64 cc. 8 cc. 2 gal.	92	70	96	84	86	85.6	85.4
3	Dichloroethyl ether *Tergitol 7* Water	32 cc. 4 cc. 1 gal.	28	60	36	22	28	34.8	33.8

[1] Difference between means necessary for significance at odds of 19–1 = 25.2%.
[2] Difference between means necessary for significance at odds of 19–1 = 4.98%.

trant per gallon and that obtained with the same solution containing half as much *Tergitol* or approximately 0.05 per cent.

Tests with *Phyllophaga* grubs were made August 6, 1941, in a heavily infested bluegrass pasture. Each plot was 5 by 8 feet and separated from the other plots by a 2-foot untreated border strip. The natural population of third instar *Phyllophaga* was unusually uniform, averaging 100,000 grubs per acre or 85 grubs per plot. The soil was very dry at the time of treatment and grubs were not feeding actively. Similar tests with green June beetle larvae were made September 4, 1941, on a series of 16 1-square-yard, board-enclosed, bluegrass sod plots, artificially infested with 25 larvae per plot. The results of the two experiments indicated no significant difference in the control obtained

Table 2.—Comparison of the effect of different amounts of *Tergitol 7* penetrant in dichloroethyl ether solution for grub control.[1]

No.	Treatment per Square Yard		Kind of Grub	Per Cent Larvae Dead					Mean Per Cent Control
				Replications				Mean	
				1	2	3	4		
1	Check— No treatment		*Phyllophaga* *Cotinis*	0 1	0 16	0 2	0 4	0 5.8	0 —
2	Dichloroethyl ether *Tergitol 7* Water	72 cc. 4.5 cc. 2.25 gal.	*Phyllophaga* *Cotinis*	94.1 96	88.9 96	100 92	90.5 98	93.4 95.5	93.4 95.2
3	Dichloroethyl ether *Tergitol 7* Water	72 cc. 9 cc. 2.25 gal.	*Phyllophaga* *Cotinis*	91.6 100	100 84	92.8 92	100 88	96.1 91.0	96.1 90.5
4	Sodium cyanide Water	13.2 gms. 2.25 gal.	*Phyllophaga* *Cotinis*	72.7 96	78.9 100	71.4 82	92.8 88	78.9 91.5	78.9 87.3

[1] Difference between means necessary for significance at odds of 19–1 = 16.2 per cent for tests with *Phyllophaga* grubs and 11.4 per cent for tests with *Cotinis* grubs.

with the two amounts of *Tergitol* (Table 2).

Since the writers got the same results with ether solutions containing either approximately 0.1 or 0.05 per cent *Tergitol 7* penetrant, tests were run with two series of square-yard plots in which ether solutions with and without *Tergitol* could be compared (Table 3). There was no significant difference between the control of green June beetle larvae whether or not

anide solution gave the best control and was, therefore, included in many tests for comparison with dichloroethyl ether solutions.

In four experiments with third instar *Phyllophaga* larvae, dichloroethyl ether-*Tergitol* solutions containing 32 cc. of ether per gallon and applied at the rate of 2 or 2.25 gallons per square yard, gave 99.3, 74.4, 85.1, 93.4, and 96.1 per cent control. Sodium cyanide solution, con-

Table 3.—A comparison of dichloroethyl ether solutions with and without *Tergitol 7* penetrant for the control of white grubs in bluegrass sod.[1]

No.	Treatment per Square Yard		Kind of Grub	Per Cent Larvae Dead					Mean Per Cent Control
				Replications					
				1	2	3	4	Mean	
			September 18, 1941						
1	Check								
	Water	2.25 gal.	*Cotinis*	28	24	12	16	20	—
			Phyllophaga	0	0	0	0	0	—
2	Dichloroethyl ether	72 cc.							
	Tergitol 7	4.5 cc.	*Cotinis*	72	88	68	88	79	74.8
	Water	2.25 gal.							
3	Dichloroethyl ether	72 cc.	*Cotinis*	76	56	96	80	77	70.1
	Water	2.25 gal.	*Phyllophaga*	72	65.6	70	57.7	66.3	—
4	Dichloroethyl ether	32 cc.	*Cotinis*	36	40	40	40	39	23.2
	Water	1 gal.							
			September 26, 1941						
1	Check								
	Water	2.25 gal.	*Cotinis*	6	20	0	0	6.5	—
2	Dichloroethyl ether	72 cc.							
	Tergitol 7	4.5 cc.	*Cotinis*	68	60	86	92	76.5	73.5
	Water	2.25 gal.	*Phyllophaga*	85.7	44.4	43.7	88.2	65.4	—
3	Dichloroethyl ether	72 cc.	*Cotinis*	50	70	86	76	70.5	67.8
	Water	2.25 gal.	*Phyllophaga*	66.7	66.7	66.7	82.6	70.6	—

[1] Difference between means necessary for significance of 19–1 = 18.4 per cent for September 18 *Cotinis* tests and 24.98 for September 26 *Cotinis* tests.

Tergitol was used in the ether solution. The control of *Phyllophaga* grubs was similar also, whether or not *Tergitol* was included. Altho the writers were unable to find any increased killing power from the use of 0.05 and 0.1 per cent of *Tergitol 7* penetrant, they did find the material an aid in effecting solution of the ether in water.

COMPARISON WITH OTHER SOIL INSECTICIDES.—In studying materials for May beetle grub control during 1936–39, a number of tests were made with sodium cyanide solution, orthodichlorobenzene emulsion, kerosene emulsion and carbon disulfide emulsion. Of these, sodium cyanide solution gave the best control and was, therefore, included in many tests for comparison with dichloroethyl ether solutions.

In four experiments with third instar *Phyllophaga* larvae, dichloroethyl ether-*Tergitol* solutions containing 32 cc. of ether per gallon and applied at the rate of 2 or 2.25 gallons per square yard, gave 99.3, 74.4, 85.1, 93.4, and 96.1 per cent control. Sodium cyanide solution, containing 10.5 ounces of cyanide to 50 gallons of water and applied at the rate of 2 or 2.25 gallons per square yard, in the same tests, gave 84.1, 83.4, 80.9, and 78.9 per cent control (Tables 1, 2, and 4). Dichloroethyl ether-*Tergitol 7* solution at the same rate, in one test with *Cotinis* larvae, gave 90.5 and 95.2 per cent control while sodium cyanide gave 87.3 per cent control (Table 2). In most cases results for the two materials were not significantly different.

EFFECT ON PLANTS.—There was no evidence of burning or killing of bluegrass in any of the grub plots treated with dichloroethyl ether solution. In several

cases, there appeared to be some temporary retardation in the growth of bluegrass after treatment. Dichloroethyl ether was found to have a selective killing action on spiny sida, *Sida spinosa* L., and the common dandelion, *Taraxacum palustrae vulgare* (Lam.) (Templeton & Ritcher 1942). Small tobacco plants in the bed were injured slightly by the application of dichloroethyl ether solution containing 32 cc. of ether and 4 cc. of *Tergitol 7* penetrant per gallon, applied at the rate of 1 gallon per square yard; but at a rate of 2 gallons per square yard practically all the plants were killed.

trol with one application of 2 to 2.25 gallons per square yard. This dosage gave control of *Phyllophaga* larvae ranging from 65.4 to 99.3 per cent with a mean of 81.3 per cent. The same dosage gave control of *Cotinis nitida* larvae ranging from 67.8 to 93.2 per cent with a mean of 79.3 per cent.

The addition of 0.05 or 0.1 per cent *Tergitol 7* penetrant caused no significant increase in the per cent control of either genus of grubs but was beneficial in effecting solution of the dichloroethyl ether. In general, there was no significant difference between the control of *Phyllophaga* and *Cotinis nitida* larvae effected with dichloroethyl ether and sodium cyanide at optimum dosages.

Dichloroethyl ether solution had little or no effect on bluegrass when applied at dosage and strength needed for good control of grubs. Severe injury to spiny sida, dandelions and small tobacco plants was observed.—1-23-42.

Table 4.—A comparison between dichloroethyl ether and sodium cyanide solutions for control of third instar Phyllophaga larvae in sod.[1]

No.	Treatmen per Square Yard	Test	Date of	Per Cent Grubs Dead					Mean Per Cent Control
				Replications				Mean	
				1	2	3	4		
1	Check		5/6/40	2.5	2.9	0	4.7	2.5	—
	No treatment		6/4/40	3	6.7	0	0	2.4	—
2	Dichloroethyl ether	72 cc.							
	Tergitol 7	9 cc.	5/6/40	100	100	97.1	100	99.3	99.3
	Water	2.25 gal.	6/4/40	75	70	75.8	80	75.2	74.4
3	Sodium cyanide	13.2 gms.	5/6/40	84.6	71.4	100	81.6	84.4	84.1
	Water	2.25 gal.	6/4/40	81.8	82.1	89.7	81.8	83.8	83.4
4	Dichloroethyl ether	36 cc.							
	Tergitol 7	4.5 cc.	6/4/40	20	37.9	18.2	31.8	26.9	25.1
	Water	1.25 gal.							
5	Carbon disulphide 1-3-10 stock emulsion	56.6 cc.	5/6/40	21.1	20.6	9.1	15.4	16.5	14.4
	Water	3 gal.							

[1] Difference between means necessary for significance at odds of 19-1 = 12.9 per cent for May 6, 1940, tests and 10.7 per cent for June 6, 1940, tests.

SUMMARY.—Poor control of third instar *Phyllophaga* and *Cotinis nitida* larvae in bluegrass sod resulted from the use of dichloroethyl ether solution containing 32 cc. of ether per gallon, and applied at a rate of approximately 1 gallon per square yard. The same solution, with or without *Tergitol 7* penetrant, gave excellent con-

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Evaluating the Economic Status of *Phymata*

W. V. BALDUF,[1] *Urbana, Illinois*

A question every practical entomologist faces has to do with the relation the several species of insects sustain to human welfare. Concretely, the question is whether a given insect is to be rated as a friend or an enemy, an asset or a liability. But since few species fit wholly into one or the other of these two categories, our task is to determine to what extent the insect is a positive, and in how far it is a negative factor in man's economy.

The present paper is concerned with an instance of such evaluation. Broadly, it has two objectives, first, to attempt an appraisal of the economic role of our common ambush bug, *Phymata pennsylvanica americana* Melin, on the basis of 832 prey records obtained in the field near Urbana, Illinois, in the years 1938, 1939 and 1940 (See references for prey lists). The second objective is the discussion of the factual shortcomings or obstacles encountered in this attempted evaluation of *Phymata*, and which will presumably be met also, more or less, in similar attempts on any other insect.

ESTIMATED ECONOMIC STATUS OF PHYMATA.—Evaluation in this case depends on two bodies of facts. One of these is the prey records since these reflect the normal range of food choice of *Phymata* under natural conditions. The other factual basis is the economic relation, in turn, of the prey species that constitute the dietary of this predator. So far as the first class of basic data is concerned, I believe the three-year collection of prey insects made under various weather conditions and vegetational situations, such as road sides, ditch banks, railroad properties, thin woods and weedy pastures, affords a fairly substantial indicator of the taxonomic, ecological and bionomic range of the prey utilized by *Phymata*. These data are summarized in tables 1 and 2 herewith.

However, the economic and bionomic facts concerning the 195 prey species themselves now are characterized by extreme variation in respect to adequacy for conclusive evaluation of *Phymata*.

Table 1.—Prey insects by taxonomic groups.

ORDERS	FAMILIES	GENERA	SPECIES	INDIVIDUALS
Coleoptera	4	6	8	82
Hymenoptera	16	40	58	216
Lepidoptera	10	24	29	134
Diptera	16	49	87	346
Neuroptera	1	1	1	1
Hemiptera	6	10	11	52
Homoptera	1	1	1	1
Totals	54	131	195	832

This list of prey species includes a large number about which the systematic position is now almost the only information we have. This drives the evaluator to the hazardous but all too common method of inference from family relations for decisions on the economic importance and bionomics of little-known species. It is, of course, true that extensive researches have yielded volumes of data for some of the principal economic prey species, such as *Diabrotica 12-punctata*, *Feltia subgothica*, *Apis mellifica*, *et al.*, yet even here one or more aspects of the biology remain insufficiently elucidated for present purposes. The life course of any species over a period of years and under ever-changing ecological conditions resembles a motion picture, not a snapshot, hence there is room for doubt whether mathematical formulae can ever be made to express faithfully insect life and the benefits or

[1] Contribution No. 226 from the entomological laboratories of the University of Illinois.

Table 2.—Choice of prey, by orders and years.

Order	1938			1939			1940		
	Spp.	Specimens	Per cents	Spp.	Specimens	Per cents	Spp.	Specimens	Per cents
Coleoptera	6	55	22.0	4	16	5.44	2	11	3.81
Hymenoptera	17	36	14.4	27	83	28.22	36	93	32.30
Lepidoptera	16	51	20.4	14	25	8.50	14	50	17.36
Diptera	33	83	33.2	56	162	55.09	37	111	38.54
Neuroptera	0	0	00.0	0	0	00.0	1	1	0.35
Hemiptera	8	24	9.6	3	8	2.72	7	22	7.64
Homoptera	1	1	00.4	0	0	00.00	0	0	00.00
Totals	81	250	100	104	294	100	97	288	100

injuries it occasions. But until we learn somehow to reduce our data to precise terms, attempts at economic evaluation of species will constitute only rough estimates. And because of the factual shortcomings concerning most prey species taken by *Phymata*, the present evaluation is necessarily inconclusive.

The method of calculation used to reach the estimate given here is as follows. Each individual of the 195 prey species taken by *Phymata* was initially assigned an arbitrary value of 100 per cent. This number was divided into two parts, one expressing the estimated positive or beneficial importance of the individual in human economy, the other its negative or destructive importance. For example, the individual adult *Diabrotica 12-punctata* was assigned five positive per cents for its possible benefit as a potential or actual destroyer of weeds, distributor of desirable pollens, factor in the education of entomologists, alternate host of useful entomophagous parasites, food of insectivorous song birds and the like, and 95 negative per cents for the attacks made by adults on flowers, fruits and leaves and by the larvae on roots, of economic plants. These plus and minus per cents were then multiplied mathematically by the number of individuals of this species taken as recorded in the prey lists. Represented by 74 individuals found held by *Phymata* in the three years, *D. 12-punctata* thus accumulated a total of 250 positive and 7,030 negative per cents or points. The plus and minus values of each of the other 194 prey species were calculated in the same way, except in the cases of insects about which little or nothing of an economic or bionomic nature is now known. These latter were arbitrarily assigned a 50–50 rating, a disposition which prejudiced the results but little because such species form a minority and are mostly represented by small numbers of individuals.

Finally, all the positive and negative points for the entire list of 195 prey species were added together, giving 41,710 plus, and 37,845 minus per cents. The grand total economic importance then amounts to 79,555 points, or a final 100 per cent. Of this total, 52.43 per cent represents the benefit performed for man by the insects killed by *Phymata*, and 47.57 per cent the amount of injury caused him by these prey species. In other words, because *Phymata* captured and destroyed 4.86 per cent more beneficial insects than harmful ones, this predator was slightly more hostile than helpful. Accordingly it was neither clearly an enemy nor an outright ally of man, and considering all the facts, should neither be destroyed nor promoted because its injuries appear to have been almost entirely cancelled by its good services.

DEFICIENCIES IN BASIC DATA.—Because an estimate is only a more or less rough approximation of the truth, the above conclusions must be regarded as subject to modification when an adequate quantity and a mathematically accurate quality of basic economic and bionomic facts have been developed through further research. In the belief that a statement of these deficiencies will stimulate effort in this field, I have attempted to classify and characterize them herewith. The special need for the present purpose is not only more data about the prey species than we now have, but data of a more precise kind that is reducible to figures and expressible in percentages.

Size, or Quantity of Food Contents.—The nature of the factual deficiency alluded to in this topic may be readily clarified by an example. Let us assume that one sulphur butterfly (*Colias*) affords one per cent of the food required to develop and sustain one individual *Phymata* through life. How many gnats (*Sciara*), plant bugs (*Lygus, Adelphocoris*), *Diabrotica longicornis, Halictus* bees, *Pollenia* flies, and any other species of the 195 forming the prey list, must be sucked out by *Phymata* in order to obtain a quantity of food equal to that afforded by *Colias*? Thus, size is here an index of quantity of food contained in any prey species. This quantity factor may perhaps be converted into approximately precise mathematical terms by calculating the cubic contents of the prey species on the basis of careful body measurements. Thereby it might be found, for instance, that a *Sciara* contains 0.05 per cent as much ingestible substance as *Colias*.

But other questions are involved. First, the food content of any one prey species may vary with sex and ontogenetic stage, and even the individual size may differ due toqualitative and quantitative differences in diet obtained by the nymph or larva, to racial strain, parasitism or possibly other causes. Second, the predator itself exhibits differences in size, similar to those displayed by the prey species, which affect the feeding capacity. Third, *Phymata* adults or any given instar can not utilize the entire food contents of the larger prey species. Experience with this species shows that a hungry adult female utilizes in one meal approximately all the contents of a fly the size of *Musca domestica;* accordingly, some of the substance of *Colias, Apis, Eristalis, Feltia* and other larger prey forms is not ingested. This fact should perhaps be considered in calculating the percentage equivalents of the several prey species in a study of economic status.

The estimated economic role of *Phymata*, given above, does not take these aspects of size into account and will therefore probably be proven more or less erroneous when more precise quantity data are obtained.

Quality of Food Contents.—My unpublished data from qualitative dietary studies indicate that the several prey species used experimentally are not of equal value for rate of growth, size, longevity and reproductive capacity in *Phymata*. It is possible therefore that these prey forms contain substances,—perchance vitamins, of different kinds as do various fruits and vegetables that compose the diet of man. Granting for this occasion that vitamin differentiation is a marked fact, how may that differentiation affect sexual vigor or vary from male to female, and how is it related to the several kinds of insect metamorphosis, stages of development, size, vigor, longevity, reproductive capacity and voracity in the 195 prey species on the one hand and *Phymata* on the other? And, moreover, how may such regulatory effects of the supposed insect-contained vitamins be reduced to comparable mathematical terms? Since our understanding of vitamins naturally occurring in insect bodies is now incipient, the full utilization of data concerning quality of food contents in determining the economic status of *Phymata*, or other species, must obviously await much research in this field.

Economic Relations of Prey Insects.—Being an entomophagous predator, the economic status of *Phymata* will be determined further, and probably largely, by the kind and extent of the activities,—phytophagy, parasitism, predatism, scavengerism, pollination, transmission of plant and animal pathogens, oviposition, *et al.*, performed by the nymphal, larval and adult stages of the numerous species this bug will eventually be found, in addition to those now known, to utilize as prey.

The decision concerning economic position cannot be made simply by dividing the prey species into two groups, benefactors and pests, for probably no species of insect is wholly a friend or a foe. The mathematical extents to which each species falls into one or the other here constitutes the very kernel or nucleus of the evaluator's task. The relative number of plus and minus per cents will be found to differ greatly from species to species and, moreover, for each species from time to time and setting to setting, ecologically speaking.

Facts desired here concern the activities of (a) the individual insect and (b) the species. Ideally accurate mathematical evaluations are possible only from full records for every bug, bee, fly, beetle,

moth and butterfly captured by *Phymata*. Obviously even a thousand observers cannot follow a thousand individual *Apis*, tachinids or *Colias* every minute from hatching to end of adult life in order to take detailed notes on their activities with the expectation that a few of them will eventually fall prey to *Phymata*. Yet, for example, probably no two individual bees of any species (*Apis*, *Halictus*, *Andrena*, *et al.*) visit and pollinate precisely the same proportion of weed and crop flowers in their lifetimes, nor do the several individuals or species of weeds or of crops have the same dollars and cents value. What is said about bees as pollinators applies equally to beetles and bugs as phytophages, Tachinidae and Syrphidae as entomophages, and many other Diptera as scavengers and potential carriers of pathogens. Therefore, to do less than pursue the individual as suggested above compels the evaluator to make the unjustified assumption that each individual bee, fly, beetle, moth, etc., preyed upon has precisely the same performance history as every other.

Present knowledge of the economics and bionomics of the several prey species, as distinguished from individuals, ranges from high, as in the case of *Apis*, *Feltia* and *Diabrotica*, to low or zero in most of the 195 in the prey lists. When all these species are as well known, economically, as the honey bee, on which, incidentally, much research is still being done, we may hope to give *Phymata* a fairly conclusive economic rating. Entomology is indeed young, vast and challenging.

Genetic Strains or Individuality.—In my dietary studies on *Phymata* this species exhibited considerable variations in rate of growth, size, weight, longevity, and reproductive capacity despite uniform allowances of diet. Such variations may signify the existence of genetic strains within the species, or one may say with certainty there is marked individuality here. Quite probably this intraspecific variation phenomenon exists also in many, if not all other species of insects, and, if so, also among the prey species utilized by *Phymata*.

So far as economic evaluation is concerned this means that the capacity of *Phymata* to benefit or injure varies considerably from one individual to the next within a given sex. More concretely, it means that the number of positive points to be assigned to *Phymata* for its destruction of predominantly injurious insects and also the number of negative per cents deserved for killing helpful species must be adjusted up or down in accordance with (a) individual voracity, longevity, and reproductive capacity of the predator itself and (b) similar variations in ability for good or harm in the several prey species. In other words, all individuals of *Phymata* do not consume equal numbers of prey insects, even granting that the latter are uniform in size, and the individuals of the same prey species are not all of equal importance as agencies for good or harm in human welfare. If we are to replace guesses and assumptions with precise calculations in determining economic status, this phenomenon of strains or individuality must be taken into account; a large body of definite data needs be accumulated through research on this and kindred problems.

CONCLUSION.—Additional factors of importance to accurate determination of the role of insect species in human welfare might doubtlessly be introduced here, but the four treated suffice to indicate that evaluation is a difficult and major aspect of entomological work if it is to be done conclusively.—1-16-42.

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SCIENTIFIC NOTES

Control of the Striped Blister Beetle through Its Gregarious Habits[1]

WILLIAM R. HORSFALL, *University of Arkansas, Fayetteville*

The gregarious habit of the striped blister beetle, *Epicauta lemniscata* Fab., which makes it a destructive pest of gardens, at the same time makes feasible an otherwise expensive chemical method of control. The sudden appearance of a roving swarm of these beetles and the swiftness with which even a swarm of moderate size destroys certain row crops require quick application of counter measures if loss is to be averted. Insecticides in the form of dusts and especially fluosilicate dusts have been most often used, but they are limited in usefulness because of the undesirable residue deposited on leafy vegetables and on fruit near harvest. Rotenone-bearing dusts which may be used without fear of undesirable residues have been found to give economical and effective results with this species.

The striped blister beetle is a sporadic pest but scattered outbreaks occur in gardens in Arkansas each year, especially in those areas where alfalfa is widely grown. The importance of alfalfa is caused by the fact that fields of it provide assembly centers for the destructive hordes. As long as succulent food is plentiful, a swarm remains in the alfalfa where its feeding usually goes unnoticed because the number of plants in excess of beetles is great. When a crop is cut for hay, the beetles fly in a body to some other suitable food supply. If garden crops are attacked, the feeding is very damaging because the relative number of plants and beetles is reversed

A swarm of this species may contain several thousand beetles and may be of such a density that when all are huddled in the shade during the heat of the day several hundred may occupy 1 square foot. In alfalfa fields, a swarm may increase in size as it moves slowly about by coalescing with others or by adding newly emerged beetles. At other times, it may decrease in size by drawing out into a tenuous body from which segments become detached. In a garden, the mass is compact and remains as a unit unless the swarm is scattered by attempts at control.

CONTROL EXPERIMENTS.—Tests with derris dust were conducted at the Arkansas Agricultural Experiment Station at Fayetteville in the summer of 1941. Dilutions of a commercial derris dust containing 4 per cent rotenone were used in all cases. These dilutions were made by adding one or three parts of talc by weight to one of the commercial product to produce dusts carrying two or one per cent rotenone.

CAGE TESTS.—Cage tests were carried out in cubical screen cages with a capacity of nearly 8 cubic feet, and in each case, 100 beetles were used. Dusts were applied through the screen by means of a small bellows duster which covered beetles, food, and cage floor alike. Beetles were confined to the cages until records were taken.

As soon as a dust application was made, the beetles acted in much the same fashion as when disturbed in the field. Later they became quiet, and began cleaning themselves by first raking their long legs over their bodies and then by dragging them through their mouthparts. Several hours later the beetles became sluggish, and 24 hours later they began to die.

The dust bearing one per cent rotenone killed an average of only 58 per cent of the beetles in two tests, so it was discontinued. In its place a dust containing two per cent rotenone was used. Kills with it ranged from 79 to 97 per cent, and the average kill in all tests was 91 per cent with this dilution.

FIELD TESTS.—Evaluating field control of this species is difficult because a swarm breaks up so readily when disturbed. It is almost impossible to obtain an accurate percentage of kill where dusting is carried out in row crops, because most of the beetles scatter before the insecticide takes effect. For this reason, results of tests in gardens are not cited. In cover crops such as alfalfa, dispersal is less extensive because of abundant cover, and effectiveness of dust applications may be more readily observed.

Two tests conducted in alfalfa fields in late July serve to illustrate field results. In each, about one pound of a dust mixture containing 2 per cent rotenone was applied by means of a rotary duster. Because dusted beetles scatter widely, the ring of dust was applied outside the confines of the swarm before it was directed at the beetles. Then the swarm was dusted in concentric rings from outside to center, in order to be sure that all beetles came in contact with the dust.

The first swarm dusted was composed of several thousand beetles occupying an area about 20 by 25 feet, near the middle of a five-acre field of alfalfa. Two days after treatment very few live beetles were found in the field. Dead ones were thickly scattered over an area about twice that occupied by the swarm in the beginning.

The second swarm occupying an area roughly 50 by 8 feet was found near the margin of another small alfalfa field. It was dusted in the same manner. Again large numbers of dead beetles were scattered about. Some escaped this time to form a small group a few yards from the location of the swarm at the time it was dusted. Even so, an estimated 80 per cent was killed.

SUMMARY.—Dilutions of commercial rotenone-bearing dusts kill adult striped blister beetles. A dilution made with talc and containing two per cent rotenone gives control ranging from 79 to 97 per cent under cage and field conditions. The habit of feeding incompact swarms makes dust applications economical as well as efficient.—4-8-42.

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Killing Codling Moth Larvae with Low Temperatures[1]

L. HASEMAN, *University of Missouri, Columbia*

The immediate purpose of this study of the effect of low temperature on codling moth larvae has been to determine the possibility of more effectively utilizing normal low winter temperatures in reducing the carry-over of larvae in the apple orchards of the state. We in Missouri have not as yet fully solved our codling moth problem, unfortunately. We are vitally interested, therefore, in making every possible use of natural factors for supplementing the

[1] Contribution from the Dept. of Entomology, Missouri Agr. Experiment Station, Journal Series No. 851.

growers' control by means of sprays and orchard management. In years past, with winter temperatures dropping to as low as 25° below zero Fahrenheit, we have lost our experimental larvae and, on occasions, almost 100 per cent of the larvae above the snow line on the apple trees have been killed by the cold. For the present, therefore, we are less interested in the technical questions of the influence of bound water, action of colloids, etc., though as the investigation progresses these factors will be considered. Right now we are more interested in determining what are the lethal low temperatures for the codling moth larvae where the question of frequency and rapidity of temperature changes, air and cocoon moisture, previous cold-hardening and protection afforded by the cocoon, tree trunk, packing shed and snow coverage, and other factors are all taken into consideration.

The specimens used in these experiments were collected, in part, under bands in an orchard in the southwest part of the state and, in part, from one in the southeast part of the state. They were induced to enter strips of corrugated paper, in which they were stored at outdoor temperature until needed. Refrigeration equipment has been used which provides a range of temperature from 50° above zero to 30° below zero Fahrenheit, and the equipment maintains quite constant temperatures at the experimental levels for the exposure periods used. The zone of low temperatures which has been most critically studies is from 14° F. to −15° F. All these observations have been made in the laboratory and no attempt has been made to translate them to outdoor winter orchard conditions. The study is still largely in the exploratory stage, but it has progressed far enough to indicate some general trends and to justify the following general conclusions:

(1) Alternate chilling and thawing of codling moth larvae which have already spun up for the winter does not seem to affect them seriously, providing the temperature changes are not too rapid, the minimum temperature is not lower than 22° F., they are not kept at the low temperature more than 24 hours at one time, and the larvae are not permitted to weaken themselves by activity between chillings. Larvae in cocoons in strips of corrugated paper have been passed repeatedly from room temperature to a minimum of 22° F. under the above conditions without seemingly causing them any harm. However, when the larvae were removed from their cocoons and kept in glass vials, where they spun much silk and weakened themselves through continuous activity, some were killed by alternate chilling to 22° F. and thawing.

(2) Of the thousands of larvae subjected to different combinations of lethal low temperatures a small percentage has been found to show definite resistance to cold. These same cold-resisting larvae when re-subjected to killing low temperatures along with other fresh larvae have continued to survive the low temperature better than the lots of fresh larvae. However, results to date do not indicate that they develop any added resistance to cold as a result of repeated subjection to low temperatures.

(3) Of the larvae showing resistance to cold in the various tests, there has been a slight predominance of females. In only a few tests has the number of resistant male larvae equalled or exceeded that of females. Also, in the less severe tests, the number of surviving females has been somewhat larger than that of males. In the more severe tests, it has been observed that, generally, the few survivors have been the larger, plump specimens in both sexes, and since the females tend to be larger than the males this fact, rather than sex, may account for the somewhat larger survival of females.

(4) Mortality is greater with a rapid chilling from room temperature to the zone of fatal low temperature than when the larvae are chilled slowly, but present available data does not indicate how much greater.

(5) Mortality is increased by moistening the corrugated paper and cocoons before subjecting them to low temperatures.

(6) Within the zone of fatal low temperature the length of exposure determines the percentage of mortality, other things equal.

(7) The zone of fatal low temperature for hibernating codling moth larvae, as indicated by these experiments, is from 10° F. to −15° F. with the fatal exposure period rapidly decreasing between 0° F. and −15° F.

(8) The minimum fatal temperature has not been definitely determined but these results indicate that it is probably close to −15° F.—3-12-42.

Sprays to Kill Overwintering Codling Moth Larvae

M. A. YOTHERS, F. W. CARLSON, and C. C. CASSIL,
U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine

Experiments with sprays against overwintering codling moth larvae were begun in 1930, and during the spring of 1941 a few of the more promising materials developed in the laboratory were tested in the orchard.

Each spray was tested on four medium-sized, badly infested Rome apple trees that were covered with rough bark on the trunk and scaffold limbs (Fig. 1). The sprays were also applied on younger Winesap trees in duplicate for purposes of determining tree injury. Oil sprays with no added toxicant were applied to single Rome trees.

Ten-gallon quantities of each spray formula were prepared in the laboratory and applied to the trees by means of a power sprayer equipped with a 28-

FIG. 1.—Rough bark on trunk and scaffold limbs of the Rome trees used in these tests.

Table 1.—Results of orchard tests of sprays against overwintering codling moth larvae. (Trees sprayed March 14–18 and examined April 8–19.) Yakima, Wash., 1941.

TOXICANT, PER CENT	EMULSIFIER, PER CENT	PENETRANT	STOVE OIL	INDIVIDUALS, NUMBER	MORTALITY
Nicotine sulfate	Ethanolamine oleate				
1	5	4%	20%	1,210	97.4%
			15	684	89.2
0.5	5	4	20	668	49.3
			15	741	82.2
Pyrethrum extract					
2	3	1	20	645	91.0
			15	649	92.8
1	3	1	20	1,002	91.0
			15	654	83.3
4–6 Dinitro-ortho-cresol	Sodium-lauryl sulfate				
1	0.5	3	10	1,070	95.3
			5	1,004	[2]69.0
0.5	.5	3	10	1,075	93.9
			5	900	77.7
Dichloroethyl ether	Ethanolamine oleate				
5	5	4	30	1,119	96.9
			20	1,229	98.1
3	5	4	30	1,195	98.6
			20	1,474	96.2
	3	1	20	436	1.1
			30	189	20.6
			25	47	12.7
			20	79	5.1
None	5	None	15	49	5.1
			10	227	[2]21.5
			5	295	1.7
	None	None	None	246	2.0

[1] Including 2.0% natural mortality in all tests.
[2] Solution of dinitro-o-cresol not complete.
[3] In moist grass and rubbish against base of tree.

gallon supplementary tank and having a pressure of about 160 pounds. A single bordeaux-type nozzle attached to a 30-inch pipe extension throwing a narrow fan-shaped spray was used. About 2 gallons of spray was used to thoroughly drench the trunks and scaffold limbs up to 7 or 8 feet. From 2½ to 3 minutes per tree were required to apply the spray.

Four toxicants were used, as follows: Nicotine sulfate (40 per cent nicotine), pyrethrum extract (pyrethrins content 2.5 per cent by weight), 4–6 dinitro-ortho-cresol (sometimes erroneously referred to as 3–5 dinitro-ortho-cresol), and dichloroethyl ether. They were emulsified in stove oil and water with either ethanolamine oleate or sodium lauryl sulfate. Analysis of the stove oil, as furnished by the Insecticide Division of the Bureau of Entomology and Plant Quarantine, was unsulfonatable residue 70 per cent, viscosity 32 seconds Saybolt at 100° F., and a distillation of 80 per cent between 189° and 257° C. The ethanolamine oleate consisted of oleic acid 282 g., monoethanolamine 62 g., and water 10 liters. Sodium carbonate was employed to release the nicotine alkaloid from the nicotine sulfate (0.62 per cent in the 1-per cent solution and 0.32 per cent in the 0.5-per cent solution).

Laboratory tests had indicated that a wetting agent or penetrant was necessary to carry the toxicant into the cocoon. Ethylene glycol monobutyl ether 50 per cent and trichloroethylene 50 per cent was used for this purpose.

Pupation had just begun at the time of spray application on March 14 and 18, but was well under way when the examinations were made on April 8 to 19. Larvae and pupae imbedded in various kinds of debris in crotches and wounds were readily affected by the sprays; the masses of trash had apparently served to absorb and hold the spray rather than to protect the larvae against wetting. All larvae and pupae found, whether in crotches, wounds, under rough bark, or in the soil attached to the tree to a depth of 2 to 3 inches, were included in the counts. From 645 to 1,474 individuals were examined in each test, with an average of 957, or 239 per tree.

The results of the tests are given in table 1.

These sprays, except the 4–6 dinitro-ortho-cresol, would cost approximately 8 to 13 cents per gallon, on the basis of current quantity purchase prices. The cost of the dinitro spray, excluding the penetrant, which later laboratory tests indicated had no value with this compound, would be about 2.7 to 4.5 cents per gallon. Later tests with cheaper and more effective penetrants and emulsifiers indicated that these costs for any of the sprays may be cut in half.

No injury developed on unopened Rome buds and only slight injury from the dinitro compound and the dichloroethyl ether on partly opened Winesap buds.

It appears evident from these tests that hibernating codling moth larvae can be readily killed in their cocoons on the trees by any of the foregoing sprays. It also appears probable that these materials can be economically and safely used as an important supplementary control measure.

Further work on this project is under way.—5-3-42.

A Natural Habitat for the Black Carpet Beetle

E. GORTON LINSLEY, *University of California, Berkeley*

On several occasions in the last four or five years the writer has found the black carpet beetle, *Attagenus piceus* Oliv., breeding in chipmunk nests in mountain cabins in the vicinity of Lake Tahoe, in Placer County, and Pinecrest, Tuolumne County, California. In the spring of 1941, Dr. T. H. G. Aitken encountered the species and *Anthrenus scrophulariae* (Linn.) under similar conditions at Manzanita Lake, Lassen County. Back & Cotton (1938) have also noted its occurrence in birds' nests.

In Sierra Nevada summer resorts, occupants of mountain cabins have frequently reported injury by the black carpet beetle to woolens and other fabrics of animal origin, whereas the city homes from which the materials were transported were free from infestation. Since most of the cabins involved were known to have chipmunks nesting within the building it seems possible that chipmunk nests may have served as foci for the infestations.—5-3-42.

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Attack of the Lead Cable Borer on Asphalt Roofing Material

E. GORTON LINSLEY, *University of California*

Some of the remarkable boring habits of the lead cable borer, *Scobicia declivis* (Lec.), are well known (Burke, *et al.*, 1922). However, one intersting reaction of the species has recently come to the attention of the writer which does not seem to have been recorded previously.

Recently a large commercial building in San Jose, California, encountered difficulty with a leaking roof. An examination revealed that the asphalt roofing material, covering the concrete slabs of the roof itself, was full of holes made by the lead cable borer. The roofing material was composed of four layers of No. 15 asphalt-saturated rag felt mopped solidly with asphalt between each layer, with a cap sheet of No. 90 mineral surfaced roofing mopped on with hot asphalt. The beetles bored in at right angles to the surface and penetrated the material until they reached the concrete. The burrows were most numerous near the metal counter flashing beneath windows but were also found distant from any materials of this nature. There was no evidence that the beetles ate the asphalt since the boring dust was pushed out of the burrows as the beetles progressed.—5-3-42.

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Wood-Boring Habit of the Drugstore Beetle

E. GORTON LINSLEY, *University of California*

A number of authors (Stebbing *et al.*, 1914) have attributed wood boring habits to the drugstore beetle but all too frequently the identifications have been open to question. However, injury to books, especially to covers containing glue, paste or casein, as is well known (Back 1939). Dorn (1921) and von Lengerken (1922) have noted damage to leather trunks. It may therefore be of interest to record a recently observed case of wood boring by this insect.

FIG. 1.—Injury to bamboo mah-jongg playing pieces by larvae of *Stegobium paniceum* (Linn.).

In 1924 a mah-jongg set manufactured in China was purchased in San Francisco. The game was utilized for a year or two and then stored away and left untouched until 1941. At that time it was noticed that the bamboo playing pieces had been severely damaged by anobiids. The larvae had injured about 80 per cent of the pieces and in every case the boring was confined to the bamboo which was in contact with the back surface of the ivory face (Fig. 1). Some damage was also evident on the unpolished back surface of the ivory. Apparently, as in the case of injury to books and leather trunks, the larvae had been attracted by the glue which was used to fasten the ivory face to the bamboo. The larvae were caged and reared and proved to be the drugstore beetle, *Stegobium paniceum* (Linn.).—5-3-42.

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Toxicity of Trichloroacetonitrile to the California Red Scale

R. L. BUSBEY, H. R. YUST, and ROBERT A. FULTON, *Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture*

Recently Peters (1940) discussed preliminary fumigation tests with trichloroacetonitrile, which he found was toxic to roaches, bedbugs, and clothes moths. Tests were performed at this laboratory to determine the relative toxicity of this material to the California red scale, *Aonidiella aurantii* (Mask.).

Tricholoroacetonitrile boils at 83–84° C. and has a density in the liquid state of 1.439 grams per milliliter at 12.2° C.

Female red scales (36 days old) resistant to hydrocyanic acid gas on lemon fruits were exposed to a constant concentration of 12.0 mg. per liter for 40 minutes at temperatures of 59°, 68°, and 77° F. The scales were reared at 77° F., and those not fumigated at that temperature were held at the treatment temperature 8 hours before the exposure and 4 hours following. Six hundred scales were fumigated at each temperature (50 on each of 12 lemon fruits). The corresponding mortalities were 90.0±1.6, 97.0±1.5, and 99.2±0.4 per cent.

In other tests resistant female red scales from the field were fumigated with three concentrations of trichloroacetonitrile. The mortality of the mature insects for each concentration was as follows: 6 mg. per liter (79° F.) 22.8 per cent, 12 mg. per liter (82° F.) 96.5 per cent, and 20 mg. per liter (91° F.) 99.8 per cent. Some insects in the second molt were included, and they appeared to be more susceptible to trichloroacetonitrile than the mature insects. This fact is of interest because scales in the second molt are relatively difficult to kill with hydrocyanic acid gas.

Resistant female red scales 37 and 38 days old reared in the laboratory were fumigated for 40 minutes at 77° F. with four concentrations of trichloroacetonitrile. The concentrations and the corresponding mortalities were as follows: 7.0 mg. per liter, 46.3 per cent; 9.0 mg. per liter, 78.3 per cent; 10.5 mg. per liter, 84.8 per cent; 12.0 mg. per liter, 92.5 per cent.

Trichloroacetonitrile was incorporated with hydrocyanic acid to determine its properties in overcoming protective stupefaction produced from sublethal dosages of the cyanide. However, the results showed little promise.

It appears from the laboratory studies with trichloroacetonitrile that the compound is somewhat less toxic than hydrocyanic acid but is much more toxic than methyl bromide.

In one series of tests the lemons showed no signs of injury, but in another series, where the lemon fruits were more turgid, injury was detected at all concentrations.—1-6-42.

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An Unusual Injury to Peas by Thrips[1]

P. T. RIHERD, *Texas Agricultural Experiment Station, Weslaco, Texas*

English peas grown near Weslaco, Texas, bearing blemishes on the pods were first brought to the attention of the writer in January, 1942. As the blemishes on the pods were unlike most forms of typical thrips injury, a visit was made to the locality from which the peas came to further investigate the trouble. The damage appeared as slightly raised, light colored circular areas on the surface of the pods. Each individual area was from one-tenth to one-sixth of an inch in diameter. The condition somewhat resembled a welt on a person caused by a mosquito bite. On most of the pods these welts were contiguous producing a condition resembling a rash. When examined under a binocular microscope the condition was found to be caused by oviposition of thrips in the tissues of the pods. No pods were observed with the injury before they had broken through the keel (corolla) of the blossom. The effect of oviposition was evident when the pods had reached the length of 1 to 1½ inches. Approximately 75 per cent of the pods were affected. The same type of injury in the same general location was reported due to thrips in March 1934 by S. W. Clark.

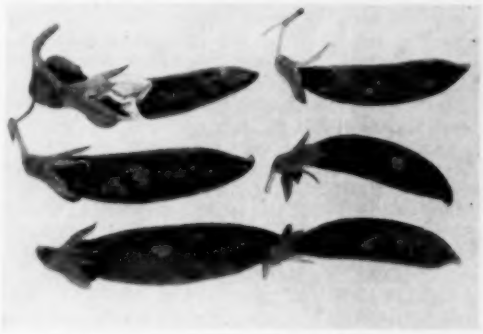

FIG. 1.—Peas showing injury by thrips.

Considerable acreages of peas are grown in the Lower Rio Grande Valley to be marketed either as fresh peas or for canning. Although the injury will not materially affect the peas produced for canning, it does mar the appearance of the peas marketed through fresh vegetable channels.

Specimens of the thrips involved were sent to Professor J. R. Watson, of the Florida Agricultural Experment Station, who identified them as *Frankliniella helianthi* (Moulton). The species was described from Visalia, California, on blossoms of wild sunflower.

According to Professor Watson it is evidently pretty well distributed in the west and seems to be a rather general feeder. No report of this species causing economic injury in the United States has been recorded in the literature.

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Observations on the Relationship of Alsike Clover Nectar to Relative Humidity[1]

H. A. SCULLEN, *Oregon State College, Corvallis*

INTRODUCTION.—The studies reported herein were part of the general program of honey flora investigations being carried on by the Oregon Experiment Station cooperating with the Federal Bee Culture Laboratory at Davis, California. The observations reported were carried on during the early part of July 1941 in the alsike clover fields of Crook County, Oregon. The present paper is a report on studies

[1] Contribution No. 740, from Division of Entomology, Texas Agr. Expt. Sta., College Station, Tex.

[1] Published as Technical Paper No. 398 with the approval of the Director, Oregon Agricultural Experiment Station. Contribution of the Department of Entomology.

Table 1.—Alsike clover nectar concentrations at certain relative humidities—1941.[1]

Nectar Concentrations	Relative Humidity
36.8	54.0
41.0	51.0
34.5	57.0
29.8	66.5
51.5	45.2
51.9	54.5
50.4	57.0
49.8	52.0
52.8	43.0
44.7	60.5
49.9	45.7
40.7	61.8
43.4	57.0
47.2	55.5
49.7	44.5
49.4	36.5
54.1	25.6
55.1	40.0
45.9	46.8
51.8	34.5
43.0	53.0
50.4	42.0
47.1	42.0
51.5	40.3
52.8	47.5
46.4	50.0
47.4	50.0
47.5	50.5

Nectar Concentrations and Relative Humidity:
N = 28
Degree of freedom = 26
Sample value of r = −.694
Standard deviation of relative humidity = 5.98
Standard deviation of nectar concentration = 8.83
Average relative humidity = 48.71
Average nectar concentration = 47.01

[1] The author is indebted to Professor H. E. Morrison, Department of Entomology, Oregon State College, for compiling the above statistics.

made to determine if there was any correlation between the nectar concentrations and the relative humidity of the atmosphere in the region of the clover blossoms.

PROCEDURE.—Nectar concentration determinations were made with the standard Abbe refractometer. The samples of nectar tested were taken from honey bees freshly killed. Twenty-five samples were taken from each of two different fields for each day during which the observations were carried on. Relative humidity was recorded with the Friez Hand Aspirated Psychrometer. Records were taken over a period of 14 days, starting with July 1 and ending with July 14.

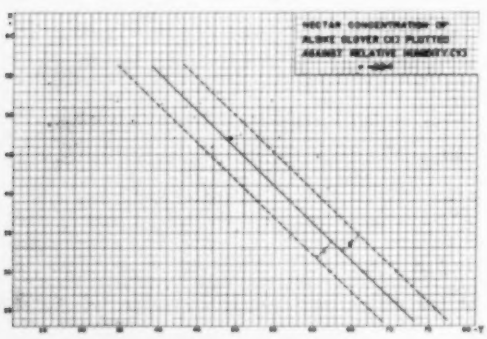

FIG. 1.—Nectar concentration and relative humidity

The weather conditions were unsettled during the early period under observation, but during the second week the atmospheric conditions were relatively settled. The readings from which figure 1 is secured are given in table 1. From the above figures and tables it can be seen that the data clearly show that the relation of relative humidity to nectar concentrations in alsike clover is highly significant in a negative manner.—2-18-42.

Orius insidiosus, a Predator on Cotton Insects in Western Texas

W. S. MCGREGOR,[1] *Texas Agricultural Experiment Station, College Station*

Numerous observations have been made of a small hemipterous insect, *Orius insidiosus* Say, preying on other insects. Uhler (1900) reported taking specimens that were feeding on aphids in flowers, and Garman and Jewett (1914) observed it feeding on corn earworm eggs on corn silks. Other entomologists have reported similar observations. These reports indicate that this predator usually feeds on small, soft bodied insects.

In the western portion of Texas some instances have occurred where the number of predators had become great enough effectively to control host insects of rather large size which were so numerous they had caused considerable damage. This seems to happen quite frequently where this particular predator works rather consistently on cotton insects. The following observations have been made at various times in that area.

During early June of 1938 many *Orius insidiosus* nymphs were seen feeding on nymphs of cotton flea hopper, *Psallus seriatus* Reut., near Spur, Texas. Within a period of 3 days the flea hopper infestation, which had been exceedingly heavy in that field, was reduced from an average of 86 nymphs to 9 nymphs per 100 plants. It was common to see one or more *Orius insidiosus* nymphs feeding on one flea hopper nymph.

In late July it was noticed when making observation on an adjacent crop of grain sorghum that a heavy infestation of aphids was being preyed upon by both nymph and adult stages of *Orius insidiosus*. At the same time it was observed that the predators were attacking recently hatched larvae of cotton bollworms, *Heliothis armigera* Hbn., feeding in the seed heads of the grain sorghum. Shortly after these observations were made, the grain sorghum was cut for silage. About this time, a severe infestation of cotton leafworms, *Alabama argillacea* Hubn., began to develop on the cotton plants next to the sorghum and in the same field which was infested by flea hoppers during the spring. The first generation of leafworms was nearly grown when *Orius insidiosus* began to attack and by the time the prepupal stage was reached, many *Orius* nymphs were present. After the larvae became webbed in the leaves it was common to see ten or more *Orius* nymphs feeding on

[1] Technical contribution No. 739, Texas Agricultural Experiment Station.

one pupa or larva that had reached the prepupal stage. On close examination it was found that over 90 per cent of the pupae were dead or being severely attacked, and over 70 per cent of the grown larvae were being fed upon by one or more *Orius* nymphs. The mortality among these leafworms was so great that a second generation was hardly noticeable. No control measures were applied at anytime, and no damage was done by the second brood of worms.

In 1941 detailed counts of *Orius* were made in September in a number of cotton fields near Lubbock, Texas, where the cotton was being severely "ragged" by the first brood of leafworms. An average of 16 per cent of the pupae webbed in the cotton leaves was dead, and a number of larvae which had reached the prepupal stage was being attacked at the time. The worms were reduced to such an extent that no second brood control measures were necessary. The weather conditions were favorable for reinfestation of the leafworms, but the *Orius* seemed to increase with the larvae and did not permit them to mature. In this instance also, grain sorghum was in an adjacent field but had been left without cutting in order to obtain the seed which had matured and were ready to be harvested. Considerable honey dew and some aphids still were present and a few *Orius* were found in the grain heads but no counts were made.

It is apparent that *Orius insidiosus* has on some occasions been sufficiently important as a predator in the control of flea hoppers and leafworms in the west Texas area so that control measures are not necessary.

The above observations add evidence to the importance of planning the crop arrangement so as to provide favorable ecological conditions which will facilitate the movement of predators or parasites from one crop to another when such predators or parasites may build up or increase on insect enemies of or common to the crops.—4-6-42.

Notes on the Biology of the Citrus Thrips

FRANCIS MUNGER, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

In the course of rearing citrus thrips, *Scirtothrips citri* (Moult.), for toxicological studies a number of observations on the biology of the thrips in the laboratory were made.

In order to measure the incubation period of the eggs, two lemon leaves were exposed at 87.5° F. to a large number of females, one leaf for 2 hours and 4 minutes and the other for 1 hour and 18 minutes. Seventy-five eggs hatched from the first leaf, which was held at 87.5° and 50 per cent relative humidity, and seventy-three eggs hatched from the second, which was held at 77° and 60 per cent relative humidity. The midtime of the exposure was used as the theoretical starting time of the incubation period. The periods required for hatching of the first larva, 50 per cent of the larvae, and the last larva were 102, 119, and 355 hours, respectively, at 87.5° F., and 169, 214, and 864 hours at 77° F.

Table 1.—Larval and pupal development of the citrus thrips at 87.5° F. and 77° F.

STAGE	HOURS SPENT IN STAGE	
	87.50°[1]	77°[2]
First instar	37+	45+
Second instar	31+	49−
Propupa	17+	23−
Pupa	37+	50+
Total	123	167

[1] Based on the average of 32 individuals, 21 males and 11 females.

[2] Based on the average of 10 individuals, 8 males and 2 females.

Data on the rate of later development are given in table 1.

In the mass rearing no counts were made on larval mortality, but mortality was not excessive when sugar was made available to the insects. (It has been observed that the insects eat less of the leaf when sugar is present.) Thirty-six newly hatched larvae reared to the adult stage at 87.5° showed a mortality of 11.1 per cent. In another experiment 430 out of 450 larvae individually transferred reached the pupal stage, a survival of 95.5 per cent.

Observations on the sex ratio of 302 laboratory-reared adults showed that 43 per cent were males and 57 per cent were females. The citrus thrips is capable of parthenogenetic reproduction. From the eggs of 9 unfertilized female thrips 188 adults were reared. All were male insects. The adult males can be distinguished from the females by their smaller size and greater activity, and the male pupae are more slender than those of the female.

As the thrips eggs are embedded in the leaves and cannot be seen, egg production was estimated in terms of larval hatch. Fifty females, one to three days old, were distributed evenly over 5 leaves. After 24 hours the insects were removed and the leaves heldat 87.5° until the eggs hatched. A total of 235 larvae was recovered, an average of 4.7 per female. In one experiment 70 females (with 60 males) produced 2,184 larvae in their lifetime. The height of production was reached about the fourth or fifth day after emergence.

An observation on longevity of 9 female thrips at 87.5° showed the minimum period in the adult stage to be 14 days and the maximum to be 33 days, with an average somewhere between 26 and 30 days. In general the males live for a shorter time than the females.—1-6-42.

Transmission of the Causal Agent of the Ring-Rot Disease of Potatoes by Insects[1]

GEO. M. LIST and W. A. KREUTZER, *Colorado Agricultural Experiment Station, Fort Collins*

The bacterial ring-rot disease of potatoes, caused by *Phytomonas sepedonica* (Spieck. & Kott.) Bergey *et al.*, was first found in Colorado potato fields by Metzger (1937). Its rapid spread under certain conditions threw suspicion upon insects as possible carriers of the causal agent. Studies made during the past season in the laboratory, and to some extent in the field, seem to substantiate this suspicion.

A number of species of insects were fed upon diseased tissue and then transferred to healthy potato or tomato plants. In this preliminary test migration of *Phytomonas sepedonica* in the plant tissue from the point of insect feeding was taken as evidence of transmission. The presence of *P. sepedonica* was determined by microscopic examination of smears

[1] Paper No. 142, Scientific Journal Series, Colorado Agricultural Experiment station.

prepared by Reed's gram-stain technique (Racicot *et al.* 1938).

The healthy plants upon which insects were placed had been grown from ring-rot disease free seed under cages that excluded insects. The potato beetles and blister beetles were confined upon only a portion of a plant, in wire neeting cages 3½ inches in diameter and 8 inches long, that closed about the stem by means of a drawstring in a cloth sleeve. The grasshoppers were confined in cloth cages that covered an entire plant. All leaves showing mechanical injuries that could be mistaken for insect feeding injuries were removed before feeding began.

Evidence of migration of the disease organism was obtained in three cases following the feeding of the potato beetle, *Leptinotarsa decemlineata* (Say).

Case 1: Adult beetles were transferred from diseased foliage after considerable leaf tissue had been eaten, to an uninfected plant August 21. A smear made October 4 from the middle of the petiolule of a leaflet upon which a feeding occurred showed *P. sepedonica* to be present.

Case 2: An adult from diseased foliage was allowed to feed upon a healthy leaflet August 27. Smears made from the middle of the petiolule of this leaflet September 8 showed the disease organism. A smear made from the base of the petiole of the leaf September 9 showed that the organism had not reached this point.

Case 3: Adults were transferred from diseased foliage to healthy foliage August 23. One smear made from the middle of the petiolule of the leaflet on which feeding occurred and another smear made from the base of the petiolule September 9 showed infection.

Brentzel & Munro (1940) state: "Grasshoppers allowed to devour considerable portions of potato plants affected with bacterial ring-rot and immediately afterwards transferred to healthy potato plants failed to transmit the disease." In the tests herein reported evidence of migration of *Phytomonas sepedonica* from feeding wounds of grasshoppers was obtained in three cases.

Cases 1 and 2: A sweeping of grasshopper nymphs and adults, most of which belonged to the species *Melanoplus differentialis* Thomas, was allowed to feed at random upon the foliage of a caged diseased plant. The insects were transferred to two healthy plants August 31. Two smears made on September 4 from the middle of the petiolule of a leaflet of plant 1 upon which feeding occurred were designated as questionable. Two smears made from other petiolules of leaflets from the same plant five days later showed the organism. One of three smears made September 4 from the middle of petiolules of leaflets of plant 2 upon which feeding occurred was gram-positive. Smears made from the bases of four other petiolules from plant 2 five days later were all negative.

Case 3: Several adults and nymphs were allowed to feed upon a cut tuber showing ring-rot symptoms and then were transferred to a caged healthy potato plant August 27. One smear from the middle of a petiolule made September 8 showed no organisms. Three of six smears made October 8 and one of three smears made October 9 from the bases of leaf petioles showed *P. sepedonica*.

Evidence of transmission was obtained in one case where the black blister beetle *Epicauta pennsylvanica* (DeGeer) was used. In this case a smear made from the middle of a petiolule of a leaflet 14 days after feeding occurred on that leaflet was marked as questionable. Another smear made from the base of a leaf petiole 36 days after feeding occurred showed ring-rot bacteria.

These results are not taken as proof that insects are a definite factor in field spread of the ring-rot disease, but they appear to constitute sufficient evidence to warrant further study of the insect relationship.—3-30-42.

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The Larval Meconium of Parasitic Hymenoptera as a Sign of the Species

STANLEY E. FLANDERS, *University of California Citrus Experiment Station, Riverside*

The meconium[1] as a means of evaluating parasitism has been used in the case of the codling moth (Flanders 1930) and the coconut scale, *Aspidiotus destructor* (Taylor 1935). The form and position of the meconium of the various parasites of the coconut scale remain unaltered long after the departure of the parasitic adults and serve to identify the species. The arrangement of the meconium of the chalcid *Comperiella unifasciata* was constant and of great value in recognition of the parasite in the field.

In the case of the codling moth egg, on the other hand, it was simply the presence or absence of the meconium which identified the genus of parasite concerned. The presence of meconial pellets showed that the egg had been parasitized by *Prospaltella* sp. The absence of meconium showed that a species of *Trichogramma* had developed within the egg. The species of *Trichogramma*, unlike most parasitic Hymenoptera, do not void the larval meconium before becoming adult. In such species the midgut, instead of opening into the hind-gut during the prepupal period, remains a blind sac until metamorphosis takes place.

Since many parasitic Hymenoptera, particularly the Chalcidoidea, lack Malpighian tubules in the larval instars (Flanders 1938) the midgut functions as a kidney as well as a stomach. Fabre (1856) stated that the midgut (*ventricule chylifique*) of the adult *Sphex* functioned as a kidney before functioning as a stomach. Long, rod-like crystals commonly occur in the lumen of the midgut of the larvae of *Comperiella bifasciata* Howard.

The discharge of the larval meconium in relation to the development of the parasite may be either prepupal or postpupal. The postpupal meconium usually is deposited after the parasite leaves the host. However, when a parasite that voids all of its excreta as postpupal meconium is forced during the larval stage to consume an extraordinary amount of food, the discharge of the meconium may be neces-

[1] Meconium is excreta stored in the intestine during development and voided just before or after the pupal period.

sary before it is able to emerge from its host. This appears to be so with *Trichogramma* (Flanders 1935).

The fact that the larval meconium in some species is voided by the adult was noted in the parasites of the fruit fly (Pemberton & Willard 1918). The braconids, *Opius humilis*, *Diachasma tryoni*, and *D. fullawayi*, retain the larval meconium throughout the pupal stage and void it after emergence. The pteromalid, *Pachycrepoideus dubius*, and the serphoid, *Galesus silvestri*, on the other hand, discharge the larval meconium prior to pupation. In the latter type of species the meconium voided after adult emergence is insignificant. According to Pemberton & Willard, the eulophid, *Tetrastichus giffardianus*, discharges larval meconium before pupation and after becoming adult. The material discharged during the prepupal stage, however, was barely perceptible and may have been material secreted by the iliac glands. In *D. tryoni* during pupation the unvoided waste and accumulated food which filled the larval midgut is forced to occupy a greatly reduced space. In the pupa this material in the form of a compressed pellet may remain in the midgut or pass into the hind-gut.

Clancy (1938) noticed in the serphoid *Helorus paradoxus* that the larval meconium was reduced in bulk by the substraction of fluids. This he considered necessary because of the spatial requirements of the abdominal organs of the adult. In the larva of this species, unlike many Hymenoptera, the meconium is enclosed in a peritrophic membrane.

The secretion of a peritrophic membrane is determined by the kind of food ingested by the larva (Wigglesworth 1939). Individuals feeding only on fluids void fluid or semifluid meconium unenclosed by any membrane.

The chalcidoid, *Melittobia chalybii*, discharges two types of prepupal meconium differing in quantity, color, and consistency. The meconium of larvae that have fed only on the blood of the host is small in quantity, semi-liquid and yellowish, solidifying after exposure to air. Larvae that ingest for the most part tissues other than blood discharge a large amount of dry meconium in the form of a chain of pellets, gray in color (Schmeider 1933).

Although larval meconium is of little, if any, value in identifying the species of a genus, it may be of value in the recognition of the species which compose the parasitic fauna of a host in the field.—5-8-42.

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Insect Pests Breeding in Vegetable Refuse in Arizona

C. C. DEONIER, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

The improper disposal of vegetable refuse in the fruit and truck-crop areas of Arizona has created a menace to public health in that lettuce refuse has been found to be one of the principal breeding places of the common housefly, *Musca domestica* L. Other species of insects, especially *Drosophila*, were found breeding in grapefruit peels from the juice canneries in such large numbers as to cause annoyance. A brief survey of the problem was made by the writer in the spring of 1938.

A large tonnage of grapefruit peel from the cannery at Tempe had been dumped on overflow land along the Salt River, about a mile below the town. At Yuma the peel had been dumped along the railroad right-of-way in the outskirts of town and in piles on waste land about a half-mile from town. Grapefruit peel in decomposing breaks down into a soft mush, which makes an ideal breeding medium for *Drosophila*. Swarms of *Drosophila* migrated into the town, where they were attracted to garbage pails and fruit stands, and passed readily through screens into homes to any exposed fruit.

On repeated occasions bananas that had been sold as edible were found to be infested with larvae. These infestations were not noticed by the public because of the small size and the color of the larvae.

Drosophila reared at Tempe in March from grapefruit peel was identified as *repleta* Woll. and that from Yuma as *melanogaster* Meig. (det. by C. T. Greene).

In July *Carpophilus hemipterus* (L.) (det. by E. A. Chapin) was taken on fruit in the local markets and was traced back to the grapefruit disposal heaps, where it was breeding in large numbers.

Musca domestica L., *Muscina stabulans* (Fall.), and *Muscina assimilis* (Fall.) bred from lettuce in March were identified by D. G. Hall. Cull lettuce dumps were found to be one of the principal breeding places for houseflies in the Salt River Valley and at Yuma. Cull lettuce is utilized to some extent to feed livestock. In many cases the methods of feeding were wasteful, and quantities of decomposing lettuce accumulated, in which houseflies bred. Large quantities of lettuce were hauled to the nearest waste land and in dump trucks (such trucks as were examined were of 3-ton capacity) and left in piles, which made ideal breeding places for houseflies. These conditions resulted in a housefly problem in the urban as well as the rural communities. The indignation of the people in the vicinity over some of these refuse heaps resulted only in the selection of a new dumping area, where housefly breeding proceeded unchecked.

Blowfly traps baited with liver at Tempe, Somerton, and Yuma took large catches of houseflies. The number of houseflies taken in these traps is indicative of the large number breeding in vegetable refuse, since this was the main breeding source at Yuma and

one of the primary sources in the Salt River Valley. From May 15 to May 29, 1937, the trap at Tempe took 31 quarts of flies, of which 86.6 per cent were houseflies. The trap at Yuma took 29 quarts in an 8-day period ending March 27, 1937. This catch was 87.8 per cent houseflies. The traps at Tempe and Somerton in May 1938 took from 20 to 30 quarts of flies in 2 weeks. Houseflies constituted 50 to 60 per cent of these catches.—4-3-42.

Analytical Isolation of Rotenone from a Spray Solution[1]

FRANCIS A. GUNTHER, *University of California Citrus Experiment Station, Riverside*

In connection with the current development of certain toxic spray solutions for the California red scale, *Aonidiella aurantii* (Mask.), it was thought expedient to determine the effect of a mutual solvent upon the stability of the contained rotenone. It was desired particularly to determine if the decomposition (inactivation) of rotenone was accelerated in the presence of the mutual solvent, *Cardolite 627*, when both materials were in a kerosene solution. None of the reported methods of analysis for rotenone are quantitatively applicable to such a solution, either because of the extremely small amount of rotenone originally present or because of the manipulative hindrance introduced by the *Cardolite*. Accordingly, a new method for the isolation of rotenone from such a spray solution was developed.

This method involved merely the application of the principles of chromatographic adsorption to the problem of the quantitative separation of pure rotenone from the other substances present in the spray mixture. After this combined separation and purification, the quantity of recovered rotenone could be determined colorimetrically or polarimetrically; the concentration of rotenone was obviously too small to allow a gravimetric determination in this preliminary investigation.

Among the adsorbents tested were powdered cane sugar, hydrated lime, hydrated lime and sea sand, calcium carbonate, magnesium oxide, magnesium oxide and sea sand, and ignited alumina. The developing solvents tested were kerosene, petroleum ether (30–60° C.), and diethyl ether. Acetone was used as the eluent.

Two equally satisfactory procedures were developed. The choice of procedure depends upon the method of final analysis of the rotenone: in the first method the rotenone may be determined either colorimetrically or polarimetrically; in the second method only a colorimetric analysis is possible without undue loss of material through necessarily excessive manipulation. Both adsorption methods result in complete separation of rotenone and deguelin from the other constituents of the original solution. This fact was determined by tracing the passage of the rotenone along the column by means of ultra-violet light (rotenone exhibits a bluish-green fluorescence), marking the zones with an indicator, fractional elution followed by the application of the author's modification[2] of the Gross & Smith color test to the eluates, and, as a final check, fractional elution followed by a polarimetric analysis of the eluates.

PROCEDURE I.—One volume of the standard toxic "stock solution" (Ebeling 1941), containing 0.25 per cent rotenone by weight, was diluted to 10 volumes with kerosene. Twenty ml. of this solution was passed through a 2 by 22 cm. column of magnesium oxide and ignited sea sand (1:2 by weight) with suction. The column was developed with 125 ml. of petroleum ether (30–60° C.). The following chromatogram was produced:

	Centimeters	*Zone*	
Top:	1.5	I	Colorless zone with no fluorescence and no color reaction.
	18.0	II	Light orange zone with no fluorescence and no color reaction (*Cardolite*).
Bottom:	0.5	III	Intense yellow zone with bluish-green fluorescence and intense color reaction for rotenone and deguelin.
	2.0	IV	Colorless zone with no fluorescence and no color reaction.
Filtrate:		V	Colorless with the light yellowish-green fluorescence of kerosene but with no color reaction.

The yellow zone (III) contained all the rotenone. It was completely eluted with three 25 ml. portions of acetone. The resulting solution was then analyzed for rotenone by the standard methods mentioned previously.

PROCEDURE II.—Twenty ml. of the diluted stock solution was passed through a 2 by 22 cm. column of ignited C.P. alumina with suction. The column was developed with a 2:1 mixture of petroleum ether (30–60° C.) and diethyl ether. The following chromatogram was produced:

	Centimeters	*Zone*	
Top:	1.0	I	Yellowish-brown with no fluorescence and no color reaction.
	2.0	II	Beige with no fluorescence and no color reaction.
	0.5	III	Yellowish-brown with no fluorescence and no color reaction.
Bottom:	18.5	IV	Purplish-tan with no fluorescence and no color reaction.
Filtrates:		V	Colorless with bluish-green fluorescence and intense color reaction for rotenone and deguelin.
		VI	Yellowish-brown with no fluorescence and no color reaction.

The colorless filtrate (V) contained all the rotenone, most of the kerosene, and a little of the developing mixture. This solution was analyzed for rotenone colorimetrically after removal of the two "ethers" *in vacuo*.—1-23-42.

[1] This work is part of a research program made possible by a grant from the Irvington Varnish and Insulator Company to the University of California Citrus Experiment Station.

[2] To be published elsewhere.

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Control of *Brachyrhinus sulcatus* Fab. in Southern California

DAVID B. SCOTT, JR., *Portland, Oregon*

In a previous note (Scott 1941) the author discussed some of the biological characters of the black vine weevil, *Brachyrhinus sulcatus* Fab., as associated with nursery stock in southern California. Experimental control work under way at that time is presented herewith.

Successful control of any insect requires a thorough knowledge of the life history of the pest in question. This rule is especially applicable when dealing with the black vine weevil since its feeding habits vary markedly within short periods of time. During the fall and early winter months in southern California the injury by the larval stages to such plants as azaleas and camellias in nurseries is evidenced by partial or complete girdling of the upper roots and lower part of the main trunk (Fig. 1). Control measures for the larval stages are not only difficult but also somewhat impractical in these nurseries.

The adult weevils, all of which are parthenogenetic, emerge in May and June, and the feeding or preoviposition period which follows offers the best opportunities to control all stages of the pest by killing the adults before the eggs are laid. From the time the weevils emerge from the ground until they prepare to lay eggs, a matter of 4 to 10 weeks, they feed quite freely at night on the upper foliage of the azaleas and camellias. During the egg laying and thereafter feeding is so desultory that control measures are uncertain.

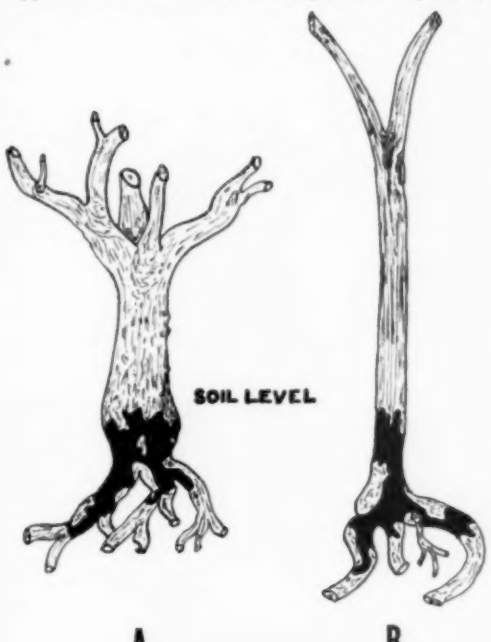

FIG. 1.—Typical girdling of plants as indicated by shaded areas.
A—Azalea. B—Camellia.

Natural cryolite especially prepared for use as an insecticide[1] used in sprays fulfills the requirements of a nursery spray better than any other material available in that it is practically invisible on the foliage, does not burn or otherwise injure the tender foliage of the azaleas or camellias, remains fully toxic as long as it adheres to the leaves, is compatible with most spray materials used in nurseries, and, like other fluorine compounds, apparently exhibits a specific toxicity for brachyrhinid weevils.

[1] *Kryocide.*

Tests were made on large blocks of plants known to be infested in three nurseries in southern California. In order to take advantage of the feeding period as well as the lagging emergence of weevils, the preoviposition period was assumed to be five weeks. The first spray, in which natural cryolite was included at the rate of 4 pounds per 100 gallons of a 1 per cent petroleum oil spray for scale insects, was applied four weeks after the first adult weevils were noted in the lath houses. Twenty-four hours after the spraying, live weevils were present in large numbers, but at the end of thirty-six hours not a single living weevil could be found, indicating that the toxic action of the cryolite, though slow, was efficient. Another spray similar to the first was applied six weeks later to control late emergence. This latter application in one nursery was also aimed at a severe infestation of Fuller rose beetle, *Pantomorus godmani* (Crotch), on which excellent control was obtained. It should be noted here in passing that infestations of loopers and spring cankerworms which appeared at this time were successfully checked by the cryolite.

It remained for the fall and winter repotting operations to check more thoroughly on the extent of control, by counting the number of larval offspring from adult weevils which escaped the spray treatment. The repotting of the plants to larger containers allows a more complete inspection of the entire stock than would be possible otherwise. In the transfer of plants in the year previous to the use of the spray program given above, the damage from the black vine weevil larvae ran as high as 15 to 20 per cent, all such damaged plants being discarded as a total loss. In the replanting process during the winter following the spraying program, out of many thousands of repotted plants, three live larvae were found in one nursery and five in another nursery; this represented a small fraction of 1 per cent damage after one season of control. A count from the third nursery was not available.

An identical spray program will be followed this spring with the hope that the infestation of the weevil can be completely eradicated in the three nurseries. Since the weevils are wingless and are not disposed to migrate any distance by foot, careful inspection of all host plants imported into the nursery should prevent reinfestation. The host plants include azalea, cyclamen, camellia, gardenia, rhododendron, yew, and many others as listed by Smith (1932).

A spray is preferred to the application of a dust inasmuch as the spray will remain intact on the plants for much longer periods. The most satisfactory combination tried so far consisted of 4 pounds of natural cryolite and 1 gallon of a miscible, medium petroleum oil in 100 gallons of water. The compatibility of the oil with the cryolite should be verified before the two are used in combination.—3-23-42.

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The Prickly Pear Cactus Thrips, *Rhopalothrips bicolor*

STANLEY F. BAILEY, *University of California, Davis*

In unforeseen ways insects described by assiduous systematists come into prominence. Such is the case with *Rhopalothrips bicolor* described by J. D. Hood in 1912[1] from the vicinity of Monteroy, Mexico. For thirty years nothing has been seen of this thrips since it was first collected in 1908 on *Opuntia* cactus.

About fifty years ago Italian immigrants brought from Sicily to the San Jose area of California a choice, edible variety of prickly pear cactus, (*Opuntia*). Many Latins are fond of the fruit and the demand for it in the tenement districts of the larger cities has resulted in the growing and shipping of the prickly pears to a limited eastern market. About 1927 sizable plantings were begun in San Jose and neighboring localities. Nearly 50 cars of

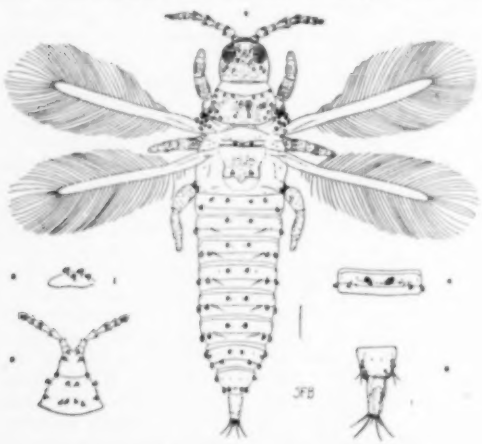

FIG. 1.—The prickly pear cactus thrips, *Rhopalothrips bicolor* Hood.

1. Adult female.
2. Left fore wing of brachypterous female.
3. Head and pronotum of mature larva.
4. Dorsum of fifth abdominal segment of brachypterous female.
5. Terminal abdominal segments of male.

Line at right of 2 and 5 equals 0.01 mm.: that at lower left of figure 1 equals 0.1 mm. which is the magnification of figures 3 and 4.

fruit are shipped annually during the harvest season which extends from August to November. In 1938 the fruit in these plantings, totaling about 50 acres, began to show considerable scarring and cracking. By the following year (and again in 1940) nearly half the crop was lost from this cause. In 1940 the attention of the writer was called to the problem which had been previously diagnosed locally as thrips injury. The insect causing the damage proved to be *Rhopalothrips bicolor*, which had been first collected in California by R. M. Bohart on April 28, 1939 in a cactus garden at San Diego. This was the first record in the United States known to the writer. (J. D. Hood now informs me he collected it on *Opuntia* at Laredo, Texas on March 3, 1939.) On August 28, 1940, it was found in a cactus garden at Pomona, California.

It is quite possible that this insect has been distributed on potted cacti, the growing of which in recent years has become popular. As far as is known, this thrips is not injurious in Sicily or in Palestine where the native cactus fruit is commonly eaten.

INJURY.—In the spring, as the new growth develops on the margins of the previous season's pads, small "buttons" are produced. The thrips, chiefly adults at this period, migrate to the tender new growth. When abundant, the chafing of the mouthparts and the extraction of the sap from the growing points results in early desiccation of these potential blossom buds (Fig. 2). When severely injured they drop off or produce stunted, misshapen fruits. In many cases by the time the blossoms appear a network of scar tissue is evident (Fig. 2 above). During the summer both adults and larvae continue feeding on the more tender pads and developing fruit. After the fruit is fully sized the thrips are rarely seen feeding thereon but the skin splits at the constricted points or scars (Fig. 3) caused earlier—chiefly before blooming. Vinegar flies and dried fruit beetles immediately infest the cracked fruits. The injury is, therefore, of two types; the reduction of the crop by the killing of the buds, and the scarring

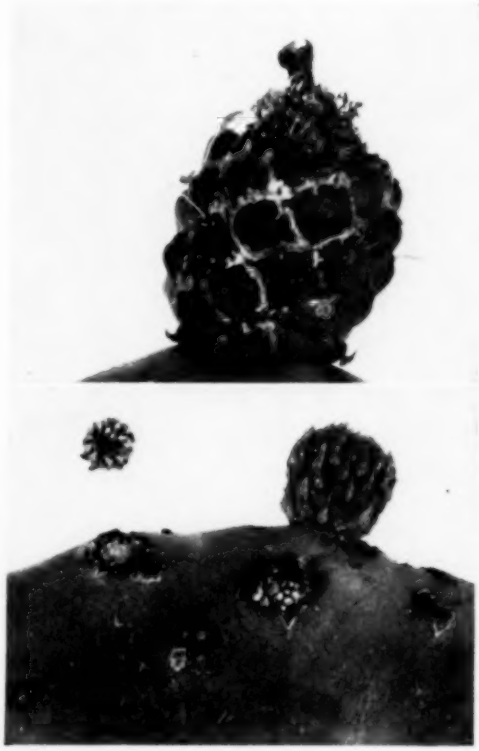

FIG. 2.—Above: Scarring of prickly pear cactus fruit by *Rhopalothrips bicolor* Hood as evidenced by the white lines demarking the sections of the small fruit. Below: Desiccated, dead buds on the margin of cactus pad caused by heavy infestations of *R. bicolor*.

[1] Proc. Biol. Soc. Wash. 25: 72–74, fig. 5, Plate IV.

FIG. 3.—Above: Thrips scarring on the surface of cactus fruit at maturity as evidence by the light, irregular blotches. Below: Many fruits severely injured by *R. bicolor* split as they mature and are attacked by other insects.

of many fruits which later are deformed and crack as they reach maturity.

BIOLOGY.—Depending on the weather and time of year, the various stages are approximately as follows: egg, 10 days; larval stage, 10 days; pupal or non-feeding stages, 6 days. The total life cycle is about four weeks. The adults live three weeks on the average and egg-laying continues irregularly over this period which results in an over-lapping of broods. The height of the seasonal population is reached in September. Lacking an ovipositor, the female deposits the minute buff-colored eggs in the dense hair which surrounds the base of the spines on the new growth. The unprotected pupae are found in cracks and depressions on the rough basal portions of the plants and under clods in the shade of the lower branches. Reproduction is asexual since females only are known in California, although Hood has collected males in Texas. During the winter months reproduction practically ceases and only a few individuals can be found hiding in the hair and behind the small bract-like leaves on the youngest pads. Both winged and brachypterous forms are usually present and migration from row to row readily takes place.

CONTROL.—Based on experience with the control of other injurious thrips, highly-refined petroleum oil combined with rotenone and pyrethrum was first tried. It was shortly observed that such oil emulsions in very small amounts (1 per cent) caused burning of the new pads. Therefore, proprietary oil-rotenone concentrates had to be eliminated. Pyrethrum concentrates alone, of course, do not give the control over a period of days of the newly hatching larvae as does rotenone residue. From this standpoint, the ground root is superior to the liquid extract which leaves but little visible residue through which crawl the thrips that survive the contact action of the spray. A 5-per cent rotenone powder used at the rate of 2 pounds per 100 gallons of water with a powdered spreader gave a very good kill. The period of effectiveness of the residue is from 3 to 7 days, depending on the temperature and amount of sunshine. Two applications about 10 days apart is desirable to reduce the seasonal infestation to a minimum. Dusts are not practical or effective because of the density and nature of the plant growth.

DESCRIPTION.—The adult female (Fig. 1) is about one millimeter long. The head and thoracic regions are dark brown to black and there are two distinct small black spots in the center of abdominal segments 2 to 7. The remainder of the body is yellow. The basal half of all femora is dark brown and the tibiae of the middle and hind legs are banded with brown. Three ocelli are present in the winged form and lacking in the brachypterous form. Antennal segments 4 and 6–8 are dark brown. The wings are transparent. The surface of the head, thorax and legs is somewhat roughed. The principal bristles on the surface of the body are infundibuliform or bell-shaped at the tip. The male is somewhat smaller having a coloration similar to that of the female. The larva is orange-yellow in color and the eyes are dark brown or purple.—1-26-42.

The Block Method of Mounting Insects

F. E. GUYTON, *Alabama Polytechnic Institute, Auburn*

The block method of mounting insects has been used by approximately 99 per cent of the students enrolled in economic entomology at the Alabama Polytechnic Institute, for the past seven years. During this period, students had a choice of making their collection by the older method of pinning the insects or the newer block method. Some of the advantages of mounting insects in blocks are: Ease of handling, exhibiting, transporting and storing, better protection from moisture and pests, and availability and lower cost of materials. Blocks containing insects can be handled by students in the class room more easily and damage to the specimens is less than when they are on pins. Pinned specimens are usually quickly destroyed when they are subjected to student handling, whereas specimens mounted in blocks may be used time after time without damage. Likewise when blocked specimens are exhibited they create more interest because they may be handled readily for close observation. Thus they present ideal material for temporary exhibits such as scientific meetings and for permanent exhibits as used by county agents, vocational agriculture teachers, pest control operators, extension entomologists and college teachers of entomology. Insects mounted in blocks are more easily prepared for transportation

FIG. 1.—Insect mounts prepared by a student.

and storage than are pinned specimens. Students who wish to keep their collections find that the blocks may be readily packed for transportation in easily obtained boxes. For identification purposes students stamp their initials into the blocks with steel dies.

Since insects mounted in blocks are enclosed in practically moisture-proof containers, there will not be much chance of their becoming mildewed. The cellophane covering protects the insect against moisture. The cellophane also gives a degree of protection against dermestids. However, it is advisable to protect stored insects by naphthalene and to prevent their exposure to mice, roaches, and ants.

The materials used in mounting insects by this new method are plywood blocks, cellophane, glue, and labels. The block is made of ¼-inch plywood and is 3½ inches long by 2½ inches wide. A hole 1 inch in diameter is bored in the block.

In developing this method of mounting insects, blocks with holes ½, ¾ and 1 inch in diameter were used. The dimensions of the first two holes mentioned did not allow enough light to fall upon the insect for clear vision for identification and display. Holes at least 1 inch in diameter are recommended. The upper edge of the hole is ½ inch from one end of the block (Fig. 1). For large insects larger blocks may be needed. The cellophane is colorless, usually of the sheet type, and may be purchased at most local 5 and 10 cent stores. A number of different glues have been used to attach the insect to the cellophane and the cellophane to the plywood block. Favorable reports have been made on *Testor's* cement, airplane glue, *Dennison's No. 32*, *Schaffer's Skrip* liquid glue, and *du Pont's* household cement. As a rule, a fast-drying glue is more desirable than a slow-drying one. Some companies make a cellophane strip with glue already on the cellophane. This material was tried but proved unsatisfactory because it greatly reduced visibility. Although variations in the method of making mounts may occur, the usual procedure is to cut the cellophane into strips 2 inches wide and long enough to wrap around the block. One end of the cellophane is glued to a lateral margin of the block and then to the back. At this point in the procedure the insect is attached to the cellophane. Care should be taken to see that only a small amount of glue is used to attach the ventral surface of the insect to the cellophane. The insect should be symmetrically oriented in the opening of the block with its anterior end nearest the top of the block. Then the cellophane is glued to the second lateral surface, to the upper surface, and finally to the edge of the block from which it started. Some workers are able to keep the cellophane tight and free of wrinkles as they glue it to the block. If the cellophane is wrinkled after the glue has thoroughly dried, it may be made taut by moistening with a damp cloth and allowing it to dry. Care must be taken not to get the cellophane too wet or it will split upon drying. For best appearance of the block the glued surface at the top and bottom should not exceed a quarter of an inch when the mount is completed. Labels should be used that will fit on the lower part of the block which is not covered by cellophane.

The blocks have varied in cost from .9 of a cent of 1¼ cents each depending on the number of blocks cut and the current cost of plywood. The cellophane, glue, and labels for 100 blocks cost about 30 cents. Therefore, the materials necessary for a collection of 100 specimens mounted in blocks should cost about $1.25. At the present time all of these materials are available. A good insect box that would accommodate 100 pinned specimens costs at least $2.00, and pins cost 50 cents per 100. Materials for a pinned collection of 100 specimens would cost approximately $2.50. Good boxes are usually available but good pins are now difficult to obtain.

It is well recognized that the block method of mounting specimens is limited in its scope of usefulness, and that it is not suitable for courses in taxonomy or for permanent institutional collections where a detailed study of the insects might be necessary for identification purposes. This method, however, is very satisfactory for such popular educational work as student collections both in college and high school, 4-H Club collections, and hobby collections.

The writer placed student collections, mounted in blocks, on display at the annual meetings of the American Association of Economic Entomologists in Columbus, Ohio, in 1939 and at Philadelphia in 1940. Collections were also exhibited at the Cotton States Entomologists meeting in Birmingham in 1941. Since that time samples have been sent by request to the State Entomologists of several states, and, with the permission of the writer, exhibits have been held at several pest exterminators' meetings, and at the State Entomologists' meeting in Oregon. A number of extension entomologists have been particularly interested in the block method for 4-H Club boys.—3-26-42.

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Beekeeping in the Emergency

BEEKEEPING is an industry in which the beekeeper often develops a philosophy that tends to make him quite self-sufficient and often self-centered. This characteristic is probably influenced by the necessity of his having to work alone so much of the time during which there is the continual need for the coordination of thought and effort in the control of a vast number of very active and often hostile insects. Each colony of bees has many of the characteristics of higher animals in that all of the members work and act together as a unit for the benefit of the colony as a whole. Thus each colony has a definite sense of industry, a typical temperament, and a pronounced degree of alertness toward self-preservation, as well as many other characteristics. Where apiary operations involve a large number of out-apiaries, the work may often keep the beekeeper out of touch with current events for days or weeks at a time. The beekeeper is essentially a producer, the same as other agriculturists who generally depend on selling the products of their labor through wholesale channels of trade.

Because the operations of the commercial beekeeper are quite removed from congested manufacturing areas, the effects, of economic emergencies are not so immediately felt as in many other industries.[1] Bees must be manipulated in the same manner although, due to rising costs of labor and a scarcity of labor and materials, the beekeeper may have to work harder and over longer hours. Few things that he actually needs are on the priority list—although the industry would be greatly handicapped without the use of tin or glass containers, tinned wire, gasoline, trucks, tires, phenol and certain machine parts and tools.

Beekeeping operations are frequently seasonal in character with periods of weeks or even of months occurring when active work in the apiary is unnecessary. During such periods beekeepers and their helpers can engage in whatever type of work they are best qualified to do in order to increase the total war effort through increased production.

The members of the Apicultural Section of the Association are interested primarily in furthering the interests of the beekeeping industry through the fields of research, teaching, extension and regulatory activities. Our functions, in time of war or in time of peace, are to improve the understanding of the beekeeper in the ways of beekeeping.

The beekeeping industry can be justified by its importance in the production of essential economic products. The honey produced annually in the United States, around 200 million pounds, adds a concentrated quick-energy producing food that needs no further processing before it is consumed. It would be lost entirely without the combined efforts of the honeybee and the beekeeper. Honey can be stored over a considerable period of time and shipped readily without much danger of spoilage. The annual production of beeswax, between three and four million pounds, is finding increasingly important uses in various channels of normal trade and in the defense industries and should be increased.[2]

During the first world war, honey production in the United States was increased considerably by intensive extension work by state and federal agencies. The increase was also influenced by higher honey prices due to a temporary shortage of sugar. During the past 20 years, lower honey prices have caused

[1] Many important events have transpired since this address was written. Beekeeping has been officially declared an essential agricultural industry, the use of rubber and tin has been greatly reduced although tin containers are available to the honey industry; a sugar shortage has developed but sugar is available to beekeepers for the purpose of feeding starving colonies; the demand for honey has increased greatly and its use for manufacturing purposes has been restricted somewhat to conserve honey for the armed forces and for home consumption. The industry is attempting to increase production of honey and beeswax by at least 30 per cent for the current year.

[2] The shortage of beeswax appears to be potentially more important in defense than was apparent at the time this was written.

commercial beekeepers to increase their colonies in order to maintain a suitable income. Many amateur beekeepers dropped out. Thus the industry is in a better position to increase production from 30 to 50 per cent if the national economy indicates this as necessary to offset a sugar shortage.

The primary benefit beekeeping renders to society lies in the maintenance of a sufficient bee force to insure the proper pollination of fruit, vegetable and seed crops. The production of honey and of beeswax may well be considered simply as valuable by-products, or as means to an end. Without the pollinating services of the honeybee, many fresh food products could not be produced at all on a practical scale. The proper pollination of pasture plants affects the food for domestic animals; thus the quantity of milk and meat products may depend, indirectly, on the bee population.

When the general economies of so many nations are dislocated by the actual participation of millions of men in the use or fabrication of war materials, it becomes increasingly important for the remainder to redouble their efforts in the production of a greater food supply. Claude R. Wickard, Secretary of Agriculture, has very aptly said, "In the day of victory when nations sit down at the peace table our food stockpiles, ready to be drawn on by the famished people of the Old World, will give great force to our views. For they will show once and for all that democracy builds for the needs of common men." One of our primary functions, therefore, should be to improve and to facilitate beekeeping practices to these ends. A better distribution of bees within agricultural areas and especially in those devoted to fruit growing and seed production should receive first consideration. The national program to produce more pastures to support more meat animals must be accompanied by increased seed production. An adequate supply of bees in the seed and pasture areas will facilitate such a program and should receive definite consideration from those in charge of these projects. Surveys will have to be made to show where a redistribution of colonies is most needed. Methods must be developed to protect bees from being destroyed by the unintelligent use of chemicals designed for the control of insects destructive to orchard and field crops. Thousands of colonies are destroyed annually by the promiscuous and careless distribution of poisonous chemicals in agricultural areas.

In order to protect the industry from the disastrous effects of the depression that will surely follow this war, it would seem desirable to advise beekeepers along three lines; first, to lower overhead costs by increased production per colony; second, to make every effort to accumulate a cash reserve before the end of the emergency; and third, to engage in a better system of marketing during the emergency in order to receive returns on their products in keeping with the rising costs of all commodities. Cooperative marketing of honey in retail and wholesale containers should be encouraged along lines that have proved successful with certain cooperatives in recent years. These cooperatives, in turn, should be represented by a central board for the dissemination of information that affects production, equipment and sales.

Studies carried on by federal and state agencies during the past few years have emphasized the influence of pollen in the economy of the colony. Studies in the field of insect physiology have increased our practical knowledge of bees. During the past two decades regulatory practices and research in bee diseases have made it possible for the practical beekeeper to control bee diseases within a workable range. Many other achievements by private, state and federal agencies have tended to place the beekeeping industry in an excellent position to maintain or to increase its services to the nation in this period of emergency. All practical phases of these services that are essential to the welfare of the nation should be continued and extended where necessary.

In closing, it seems desirable to call attention to some beekeeping research and activities to which additional attention could be given during these stressful times. We need to know more about honey and especially about its chemical and food values. Without such information honey will continue to have a difficult time in competing with the more nationally advertised sugars and syrups. We need more information about processing honey for the baker as well as for the retail trade. Honey by-products should be de-

veloped as an aid in disposing of the lower grades of honey which too often are now placed in retail containers. Many have tried and failed to produce a dry crystallized product from honey. Can this be done to an advantage?

We know too little about the environmental influences that affect nectar secretion. If a more complete knowledge were available it could be used to forecast the possibility of nectar-flows and thus aid materially in increasing production.

We need to know more about the genetics of the honeybee. Methods have been improved for the artificial insemination of queens but little has been accomplished with these techniques.

Just recently investigations have shown that the food supplied for shipping queens is practically useless under certain temperature and moisture conditions. This work should be continued until a more suitable food material or method of shipping queens is accomplished.

The regulatory authorities should take this opportunity to simplify bee laws and to abolish those regulations designed primarily as trade barriers. Particular attention should be given to the rescinding of those regulations that impede the free movement of honey or of package bees between states.

This country is noticeably lacking in any central agency for the coordination of agricultural research, regardless of the field. This produces much lost motion and needless waste of time, material and funds. Our universities, state and federal agencies, as well as private institutions, have a wealth of men and material to carry on research in all fields and a better coordination of these facilities most certainly would result in marked benefits. This Section has served as a means of interchange of ideas and results in the fields of research, teaching, extension and regulatory phases of apiculture but too few persons take part in its activities. All state and federal employees, interested in any phase of apiculture, should be members of this Section and should take an active part in its proceedings. In this period of emergency we could well clear our decks for more productive work through a greater coordination of effort in these four fields of service to the beekeeping industry.

J. E. ECKERT

REVIEWS

Cotton Insects of the United States, by V. A. Little and D. F. Martin. ii and 130 pages. Illustrated, 1941. Burgess Publishing Company, Minneapolis, Minnesota. Price $2.25

The rapid accumulation of entomological knowledge, both in extent and in detail, has increased the need for manuals which bring together information in specialized fields more completely than is possible in general works. Such a work has been undertaken by Little and Martin for the insect pests of cotton in the United States.

Taking advantage of the limited field the authors are able to give attention to at least 96 insects known to feed upon cotton, and in addition even make brief reference to nematodes, sowbugs, and crawfish. In treating the more destructive species they have attempted to include the information essential for dealing with cotton insect problems. Each discussion follows a definite pattern which includes taxonomic position, economic importance, history, description of stages, biology, natural control, and artificial control. Specific directions in procedure for the control of a few of the more destructive pests are outlined. For these species detailed descriptions are given for the successive stages. The treatment of insects of minor importance is largely descriptive and is of necessity brief, for the published records relating to many of them as pests of cotton are fragmentary. The assemblage of this otherwise scattered information is one of the distinctive features of the book. As a matter of convenience the book is divided into two parts, one dealing with the insects attacking the fruiting parts of cotton, and the other dealing with those attacking the vegetative parts. A bibliography is appended to each chapter.

The subject of cotton insect control lends itself to uniform treatment since cotton insects are largely restricted to a single region in the United States where cotton is the dominant crop. Furthermore, in control chief dependence is on insecticides, and as a rule the insecticides are applied in the form of dust. The authors have recognized, however, in the discussion of the boll weevil, that the same control measures are not equally useful in all parts of the Cotton Belt, and for this reason a number of methods are presented, not all of which are recommended in any single part of the country. There may be differences in opinion regarding importance of some of the subject matter which is included as compared with that which is omitted. Such differences always occur, however, depending upon the experience and the geographical location of the reader.

Subject matter included in this volume was originally assembled by the senior author for teaching a course in Cotton Insects at the Texas Agricultural and Mechanical College. However, it is intended to be of use not only for students but to others interested in cotton production.

DWIGHT ISELY

Naile, Florence, 1942. The Life of Langstroth, With foreword and introduction by E. F. Phillips, Ithaca, New York: Cornell University Press, 215 pp., with portrait.

All persons connected with beekeeping know that the Rev. L. L. Langstroth invented the bee hive which made modern beekeeping possible, an indispensible first step in the development of the modern honey industry. The importance of this invention alone justifies a biography of the inventor, and he is still more worthy of such a record because of his helpful influence on the infant industry. The story of his life is a long record of the overcoming of seemingly insurmountable obstacles and of service to others without ceasing, the story of a great and good man.

Langstroth was born on Christmas Day, 1810, and lived to the ripe old age of eighty-five years. He came of British, German and Huguenot-French stock, and his ancestors played worthy parts in the early days of this country. The Langstroth family long resided in Yorkshire, England, and modern maps show Langstrothdale in that shire. His education was the classical one of his time, with scant attention to the sciences, but it was his good fortune while a student to reside in the home of Professor Denison Omstead, who inaugurated laboratory work at Yale and who wrote important early papers on meteorology, physics and other lines of scientific work. Apparently from Omstead, Langstroth acquired a scientific viewpoint. Langstroth was graduated from Yale in 1831 in a class which furnished many men prominent in public life. He received the degree of bachelor of arts and was elected to Phi Beta Kappa. After graduation he attended the divinity school and was ordained in the Christian ministry.

He served two New England churches, but failing health which later led to long periods of inactivity, made a continuation of that work impossible. He then taught in seminaries for young women, apparently with success, but was forced also to give up that work. He lived successively in Pennsylvania, New England and Ohio, where he died.

The necessity of leading an outdoor life led him to take up beekeeping, using at first the crude box hives of the period. He soon discovered, as had many others before him, that bees cannot be managed properly if the combs cannot be handled, but unlike his predecessors in the art, he did something practical about it. He first adopted the Bevan hive with bars on which the combs were suspended, but these were not suitable to his needs. By an accident he learned that a narrow space between bars is not filled by the bees with either comb or propolis, but he was capable of appreciating that this "bee space" is the secret of success in a hive. Through a series of thrilling experiences he came on the idea of a movable-frame hive. A dramatic feature of this discovery was that the idea first came to him after his last day's work with his bees in 1851, so that he could not test out his theories in the apiary until spring. The evidence was so clear that during the following winter he had hives made to which his bees were transferred in spring. On the night after his concept was formulated, he wrote in his journal an amazingly clear account of what the invention would mean to the art of beekeeping if it worked, as of course it did. This journal is preserved in the Cornell Beekeeping Library, and copies of the crude drawings which he made on the night of October 30, 1851, are reproduced in the biography.

This life story will interest persons other than beekeepers. It is a strange story of a man who suffered all of his adult life from an affliction from which he could obtain no relief. It is also the story of a man who in his periods of mental vigor was devout, with never a question arising in his faith, yet who on the other hand retained a highly skeptical and acutely scientific attitude in all his work with bees. Men of such devoutness have largely disappeared, and it is worth while to have so fine a record of such a man. Men of his acute scientific attitude are still too uncommon, and it is worth while also to have that record. There have been few men of his scientific acuity in beekeeping since his day.

The author has arranged that all royalties which would have been due her from this book shall go to the endowment for the Cornell Beekeeping Library, as a memorial to the subject of this biography. The author will then receive no rewards from her long labors other than a realization of a difficult task well done, and the thanks of those who benefit from her effort. E. F. PHILLIPS.

NOTES

GEORGIA ENTOMOLOGICAL SOCIETY

Sixth Annual Spring Meeting Emory University, Atlanta, Georgia April 4, 1942

After luncheon in the Emory University Cafeteria, the group of about 22 persons assembled in the Chemistry Building where the meeting was called to order by Vice-president P. W. Fattig at 1:30 P.M. Mr. T. L. Bissell and Mr. C. H. Alden were designated to serve as a nominating committee and Dr. P. M. Gilmer and Mr. M. C. Quillian as a resolutions committee.

The report of the secretary was read and approved.

Dr. Gilmer reported for the publications committee and thanked President Murphey (called to active duty in the Army the last of March) for putting out the first issue of the *Georgia Entomologist*. He pointed out that, due to short-handedness in the office of the State Department of Entomology because of Selective Service drain, Mr. Murphey had set up the type and printed the issue entirely by himself. Mr. Gilmer also thanked the State Department of Entomology for allowing Mr. Murphey the use of the facilities for the printing.

Mr. Quillian, chairman of the membership committee, recommended that membership be extended to the following persons:

Mr. G. C. Starcher, Prattville, Alabama
Mr. Victor C. Durham, Philadelphia, Pa.
Mr. Lucian Harris, Jr., Atlanta, Ga.
Mr. H. W. Eustis, Augusta, Georgia

Recommendation was accepted on motion.

The following program was then presented:

Mr. C. H. Alden substituted for Mr. J. H. Girardeau in extending greetings to the Society from the State Department of Entomology and sketched the work of the department briefly.

Colonel L. L. Williams, U. S. Public Health Service,

reported on "Malaria Control in Defense Areas," in which he stated that about one-half of the troops now in training in the United States are quartered in areas generally recognized as malarious, many of the camp-sites having been deliberately selected to include swampy areas in order to afford the troops opportunity to practice maneuvers over difficult terrain.

Major, W. V. King, Medical Corps of the Fourth Corps Area, added comments in which he stated that early rainfall thus far this season would indicate the likelihood of increased malaria incidence.

Dr. H. O. Lund, University of Georgia and the Emory University Field Station discussed "Tests on Oviposition Preferences of the Georgia Malaria Mosquito."

Mr. H. Duke Thomas, University of Georgia, spoke on some of his "Experiments on Factors Affecting the Hatching of Mosquito Eggs," in which he demonstrated the influence of certain microorganisms, growth-stimulating substances, hormones, and mere crowding, upon the hatching of the eggs of *Aedes aegypti*.

Dr. King and Dr. Williams both commended the work and Dr. King recalled some work done recently in Oregon on the hatching of other species of Aedes.

Mr. G. L. Carver, Mercer University, spoke on "Fire Prevention Programs and Game Law Enforcement in Georgia," in which he emphasized the importance of game-birds in insect pest control and the relatively appalling fire losses in Georgia forests. Dr. B. J. Kaston pointed out that much of this burning was done deliberately by the land-owners themselves.

Dr. P. M. Gilmer, United States Bureau of Entomology, suggested that the Society cooperate in a "Survey and Reporting Service on Cotton Insects for Georgia." He described the sampling and surveying methods most likely to prove successful for the Boll Weevil, cotton aphis, cotton bollworm, and the cotton leafworm. Mr. Bissell commended the idea highly and Dr. Gilmer agreed to initiate the work.

Dr. B. J. Kaston, Brenau College, gave a very interesting discussion of "Some Common Misconceptions about Spiders," in which he pointed out that not all spiders spin webs, that the female in only rare cases ever eats the male, that not all spiders are dangerously venomous, that spiders suck not only the blood of their prey but also the solid tissue after they have been predigested by proteolytic enzymes injected in the venom of the spider.

Mr. O. I. Snapp, United States Bureau of Entomology, discussed the recent development of "Dichlorethyl-ether for the Control of the Plum Curculio on Peaches," an aqueous emulsion of which is sprayed on the ground under peach trees to kill the larvae and pupae of the curculio in the soil.

Mr. T. L. Bissell, Georgia Experiment Station, presented a carefully thought-out discussion on the pertinent topic of "cultural and Chemical Control of Insects for the Duration." He advocated the emphasis of cultural methods and the careful diagnosis of damage and the use of minimum concentrations of insecticides consistent with control.

Mr. C. H. Alden, State Department of Entomology, showed a moving picture in color on "Queen Bee Rearing in Georgia," a reel prepared by President Milledge Murphey.

The secretary was instructed to cast a unanimous ballot for the following officers: P. W. Fattig, President; O. I. Snapp, Vice-president.

C. H. Alden reported for the auditing committee that the treasurer's report was correct and recommended its approval.

H. O. Lund reported for the Insect Survey committee that approximately 4,500 species of insects had been authoritatively determined and recorded in the files of the Survey.

The Resolutions committee reported as follows:

'Be it resolved:

That the thanks of the Georgia Entomological Society be extended to the State Department of Entomology and to Mr. J. H. Girardeau, the State Entomologist, for making possible the necessary facilities and to President Milledge Murphey for editing and printing Volume I and Number I of "The Georgia Entomologist."

That thanks be extended also to Mr. T. L. Bissell for the historical article on the origin and early meetings of the Georgia Entomological Society that appeared in the first issue of "The Georgia Entomologist."

That Colonel L. L. Williams, Jr. of the United States Public Health Service accept our sincere thanks for the very instructive address and for the valuable time given by him to the Society.

That we extend our thanks to Curator P. W. Fattig of Emory University for arranging, and to the authorities of Emory University for providing, the excellent facilities for the entertainment of the Society for this, the Sixth Annual Spring Meeting."

The report was accepted unanimously and the meeting was adjourned.

A simple but effective method of exhibiting Kodachrome Slides was demonstrated by Mr. T. L. Bissell. The apparatus consisted of a large wooden box about ten inches deep and fifteen inches square, with two electric light bulbs mounted on the inside walls; and with a double glass top, the lower glass sheet being made of ground glass. The slides were placed between the two layers of glass and viewed from above.

HORACE O. LUND
Secretary-Treasurer

NORTH-CENTRAL STATES ENTOMOLOGISTS ANNUAL MEETING URBANA, ILLINOIS, MARCH 26 AND 27, 1942

The North Central States Entomologists held their 21st annual meeting in Urbana, Illinois, March 26, 27, 1942. About 200 entomological workers from 16 states and the District of Columbia were present and elected Professor W. P. Flint to serve as general chairman.

The high light of the meetings was the general session where the subject, "How Entomologists Can Best Contribute to the Victory Program and War Effort," was discussed.

The eight different topics discussed in this session related to:

The entomologists contribution to the production and protection of essential foods, fibers, and other essential supplies.

Protecting health of man and animals.

Preventing the introduction of new pests.

The effect of war upon entomological supplies and insecticides.

Research adjustments and extension procedures necessary to help the public control insect pests under war time conditions.

During the remainder of the meetings many of the entomological problems common to the area were discussed. These were grouped under general headings:

Cereal and Forage Crop Insects.
Insects Affecting Man and Animals.
Insecticides.
Vegetable and Greenhouse Insects.
Household Insects.
Beekeeping.
Fruit Insects.
Stored Products Insects.
Illustrating Insects and Their Activities.

By running three sections concurrently, it was possible to cover these nine general topics and devote approximately one-half day to each topic.

Although the latter nine subjects were not new to the entomologists, the problems arising because of conditions brought about by the war were in evidence at all times during the meeting.

The following resolutions were proposed and adopted at the Conference.

WHEREAS: The entomologists of the North Central States Entomological Conference have experienced an enjoyable and profitable visit and meeting at the University of Illinois on March 26 and 27, 1942,—we wish to submit the following resolutions:

1. Resolved: That the thanks of the North Central States Entomologists be extended to the local entomologists for the especially convenient arrangements made for the 1942 meetings *and* for the many courtesies extended to the visiting entomologists.

Also we wish to thank the other members of the University of Illinois staff who have contributed to the success of the meeting; the members of the banquet committee who arranged for the banquet program; the students and others who took part in the entertainment program; and the management of the Illini Student Union Building for the very excellent facilities provided.

2. Resolved: That the membership of this conference *express* their appreciation for recognition of the importance of the entomological profession by the Office of Price Administration, the War Production Board, and the Federal Housing Administration, and those agencies concerned with health and sanitation, *and* that further provision be made for using the services of entomologists in protecting the health and well-being of the personnel of the armed forces as well as their supplies.

Furthermore, that the services of entomologists be used for surveying and developing control measures for the more important insect pests, particularly those responsible for transmission of human diseases, n areas either now occupied or which may be occupied by the armed forces.

3. Resolved: That entomologists attending this conference wish to go on record as offering their services in whatever capacity may be needed during this emergency in the control of insect pests—*and* that the proper authority in the Bureau of Entomology and Plant Quarantine be requested—after proper investigation—to advise the several entomological training centers of the proper procedure to follow in securing appointments in those branches of the armed forces where entomologists are best fitted by training to render the greatest service.

4. Resolved: That the members of this conference commend the personnel of the Bureau of Entomology and Plant Quarantine for their alertness in developing an entomological program adapted to the war needs and for their aggressive leadership in fostering this program. Whereas the work of the Bureau of Entomology and Plant Quarantine is of even greater importance during this period than during peace times, we urge that they be allotted adequate financial support so that the necessary pest control program in connection with the war activities can be effectively performed.

D. M. DELONG
D. A. WILBUR
H. DOUGLAS TATE

The group plans to meet at Lafayette, Indiana, in 1943.

The report of the meeting is to be mimeographed and a few copies will be available from Professor W. P. Flint, State Natural History Survey Division, 123 Natural Resources Building, Urbana, Illinois. There is a small charge of 75¢ per copy to cover the cost of preparing and mimeographing the report.

COMMITTEE ON COORDINATION OF ENTOMOLOGY WITH THE WAR EFFORT—REPORT OF PROGRESS

To the Members
American Association of Economic Entomologists

In the report presented by this Committee under date of May 10, 1942, to the President and Executive Committee of the Association, the then members of the Committee on Coordination of Entomology with the War Effort proposed that they be permitted to resign to allow the President to make such changes in Committee personnel as might be deemed desirable in order to carry out the newer functions proposed for the Committee. President Weiss has reappointed all former members of the Committee and has added the name of Secretary Cory to the Committee. He also invited Dr. P. N. Annand, Chief of the Bureau of Entomology and Plant Quarantine, to nominate some member of the administrative staff of the Bureau as an additional member of the Committee, in view of the importance of the Bureau in any plan for cooperation among entomologists which may be undertaken. Mr. Avery S. Hoyt has been so nominated and has been named a member of the Committee by President Weiss.

It is impracticable to write a personal letter to each member of the Association, but the Committee hopes that each member will read this as an intimate personal appeal to him to order his activities from this time on to the end of winning the war.

In the report of May 10, attention was called to the need of re-examining our work, not for the purpose of refinement of methods but to the ends that the results may be made useful as soon as possible. This is a task for the individual, working of course in harmony with administrative officers, as well as with others engaged in similar or allied fields of entomology. The first task then for each of us is to make the necessary examination of his work to determine in what degree changes can be made which will render his particular line of work most practical, at once and for the near future.

The government, through the Department of Agriculture, has established certain goals for increased production of certain commodities. The increase in acreage of some of these crops will magnify the problem of insect pest control, making the services of entomologists more vital than usual.

There is at the moment no agency duly authorized to arrange such a cooperative enterprise as is now indicated as essential. No such agency would be considered necessary, desirable or even tolerable in days of peace, for entomologists are ordinarily individualistic. In view of the emergency now existing and of the need for cooperation at once, this Committee is taking the liberty of inviting certain entomologists to assume leadership, for the purpose of bringing together as soon as practicable the knowledge and work of the men best versed in the control of those insects that affect these vital war commodities. The committee presents such apologies as may seem to be indicated for this assumption of responsibility, in full assurance that entomologists everywhere want action at once. As soon as possible, names of these cooperative leaders will be announced.

Cooperative work can accomplish much in 1942. Still more beneficial results will be evident in 1943, and in subsequent years for the duration of the war. There is no reliable indication that this war will be short, but regardless of the duration, still more cooperation will make economic entomology a more effective service agency to mankind.

It is now pointed out, not only to the relatively few entomologists who are asked to take on special tasks, but to all entomologists, that the tasks are, first, so far as possible to come to agreement as to the best methods of control of the insect pests in question, and secondly, but no less important, to arrange that the recommended methods of control be carried promptly to growers and others who are concerned with the application of actual control measures. This will in some cases call for short, practical circulars, posters, cooperation with extension workers, cooperation with plant pathologists in some instances, and often cooperation with various federal agencies which deal with problems of agriculture. These various agencies are of course well known to all entomologists engaged in work on the control of insect pests, and the task is to determine in each instance through which agencies the best aid can be obtained to carry the essential information regarding control measures to those who stand in need of this information. It seems definitely indicated that lengthy and highly technical publications are now less needed than short and entirely practical publications. In some instances publication will answer the purposes less well than personal contacts, and in each problem, the task of the entomologists is to determine through which means the end results of effective and practical control may best be met. This decision will call for vision, ability to cooperate with others, ability to present advice and results in non-technical ways, and often a considerable departure from the methods which each of us would use in times of peace.

The Committee of course assumes no authority to dictate what any person shall do or the methods which shall be used. The Committee stands ready, to the limits of its ability, to assist any member who may wish our aid, with the understanding that the Committee does not assume to possess knowledge of the best methods to be used for any particular problem.

Certain questions will arise respecting the best plans for cooperation, and to illustrate this problem, we cite the problems of control of fruit insects. Because control measures vary regionally, the problem, for example, may arise as to whether codling moth work should be further coordinated for the entire country, or whether for immediate results the cooperation should be set up on the basis of areas, taking under consideration all insect species attacking deciduous fruits. This is an excellent example to cite, because of the high degree of cooperation which has been set up on a peace-time basis by men in codling moth work. This is mentioned to suggest that the basis for cooperation will in some instances be on a single insect species, in other instances on the basis of the crop concerned, in other instances by areas. The right way to arrange cooperation would seem to be for the leader and his associates to meet the greater practical need, not necessarily on the basis of scientific classification of insect problems.

The changing situation with regard to insecticide supplies will present serious and difficult problems in many cases, and in some instances almost as soon as practical recommendations have been issued, it may become necessary to shift emphasis to the use of some different means of control. It is already evident to all economic entomologists who advocate the use of insecticides that vigilance is necessary on the problems of insecticide supplies. Word of all changes in supplies of such materials will be issued as soon as possible by the Bureau of Entomology and Plant Quarantine. Meanwhile entomologists should, so far as possible, undertake to anticipate changes in materials, to the end that as insecticide supplies change, they may promptly issue new control measures, as good as can be devised under the circumstances. This may necessitate some ingenuity, and a reevaluation of our methods.

The Committee does not at this time desire to anticipate too specifically the problem of making known to the membership the results of the increased cooperation arising as a war emergency measure. It merely now suggests that it may be desirable at the forthcoming meeting to arrange for brief reports of the activities of various groups, not only for the purpose of making the facts known, but perhaps in some instances to intimate a need for more intensive effort on the part of some groups of entomologists. If reports be made which indicate real accomplishment and not mere promises of later effort, the forthcoming meeting will stand out as the most important in the history of the Association.

A suggested chart for cooperative endeavor is being supplied to those entomologists who have been invited to serve as leaders, in the expectation that each will set up his own organization in the manner which appears to be most effective. It will be necessary for the leader to appoint sub-leaders, by geographical regions, by crops, or in other ways, so that special problems may be adequately cared for. It will also be necessary for the leader to organize by conference or by correspondence the fundamental procedures to effect the greatest degree of control in the shortest possible time, bearing in mind of course, that through the sub-leaders there will be modifications of the general program to meet regional differences in the problems and in the methods of attack on insect pests. The program will need to be modified by the exigencies of the insecticide situation. The general procedure of getting the necessary information down to the grass roots must be worked out by the leader and his associates, and this will vary by regions and in other ways.

TENTATIVE[1] PROJECT LEADERS AND ASSOCIATES

Leaders who have been tentatively selected by Messrs. Phillips, Hoyt, Sanders and Cory after consultation with division chief and Dr. Bishopp. The goals are listed as given in the Food For Freedom Program revised, February 6, 1942. Percentages as based on 1941 production.

Milk	108%	E. M. SEARLS, *Madison, Wis.*
Poultry, including turkeys	110%	O. G. BABCOCK, *Menard, Texas*
Hogs	114%	C. J. DRAKE, *Ames, Iowa*
Beef	108%	W. E. DOVE, *Washington, D. C.*
Sheep	101%	
		Suggested associates:
		E. G. KELLY, *Manhattan, Kan.*
		CAMERON SIDALL, *College Station, Texas*
Fabrics	no goal	NEELY TURNER, *New Haven, Conn.*
Peanuts	225%	T. L. BISSELL, *Experiment, Ga.*
Wheat	88%	R. H. PAINTER, *Manhattan, Kan.*
Soy Beans	154%	W. P. FLINT, *Urbana, Ill.*
Cover Crop Seeds	137%	DON C. MOTE, *Corvallis, Ore.*
Hay Crop Seeds	125%	C. L. FLUKE, *Madison, Wis.*
Oats	102%	
Barley	106%	F. A. FENTON, *Stillwater, Okla.*
Rye	101%	
Sugar cane	no limit	J. W. INGRAM, *Houma, La.*
Hay	100%	East—F. W. POOS, *Beltsville, Md.*
		West—C. J. SORENSON, *Logan, Utah*
Sorghum	106%	F. L. THOMAS, *College Station, Texas*
Corn	108%	North—W. P. FLINT, *Urbana, Ill.*
		Suggested for the South
		ARTHUR L. HAMNER, *State College, Miss.*
Stored Products	no goal	J. J. DAVIS, *Lafayette, Ind.*, and
		R. T. COTTON, *Manhattan, Kan.*
Deciduous Fruits	100%	BENNETT A. PORTER, *Washington, D. C.*
Dried Fruit	118%	PEREZ SIMMONS, *Fresno, Calif.*
Citrus Fruits		West—A. M. BOYCE, *Riverside, Calif.*
		South—WILMON NEWELL, *Gainesville, Fla.*
Cotton Insects	108%	R. W. HARNED, *Washington, D. C.*
Tobacco	Slight increase allowed	W. H. WHITE, *Washington, D. C.*
Sugar Beets	No limitations	J. R. DOUGLASS, *Twin Falls, Idaho*
Beans		East—NEALE F. HOWARD, *Columbus, Ohio*
Green	100%	Suggested for the West
Dry	113%	L. G. SMITH, *Pullman, Wash.*
Canning Peas	132%	East—BAILEY B. PEPPER, *New Brunswick, N. J.*
		West—L. G. SMITH, *Pullman, Wash.*
Dry field peas	173%	L. G. SMITH, *Pullman, Wash.*
Tomatoes	127%	West—A. E. MICHELBACHER, *Berkeley, Calif.*
		East—R. H. NELSON, *Columbus, Ohio*
Sweet Potatoes	101%	CLAY LYLE, *State College, Miss.*
White Potatoes	110%	East—H. C. HUCKETT, *Riverhead, L. I., N. Y.*
		Central—H. B. TATE, *Lincoln, Neb.*
		West—KENNETH W. GRAY, *Corvallis, Ore.*
Farm Gardens	120%	M. P. JONES, *Washington, D. C.*
Man and Animals		W. B. HERMS, *Berkeley, Calif.*
		Associates suggested: W. A. RILEY, *St. Paul, Minn.*, and G. H. BRADLEY, *New Smyrna Beach, Fla.*
Damage to Buildings		T. E. SNYDER, *New Orleans, La.*

[1] Subject to acceptance by the men chosen and to additions to the list.

Success of this program will depend largely on the initiative, drive and vision of the leader and his associates. An attempt is being made to select a leader possessing these qualities, regardless of his affiliation or his official status, with the full confidence that every one, even though he may be a leader in the same or other fields or in another region will cooperate to the fullest extent to make these programs effective and useful. The program is designed to supplement the fine cooperation already existing among entomologists by the creation of a larger measure of cooperation, through the implementing of insect control particularly for the goals projected by the Department of Agriculture in the emergency.

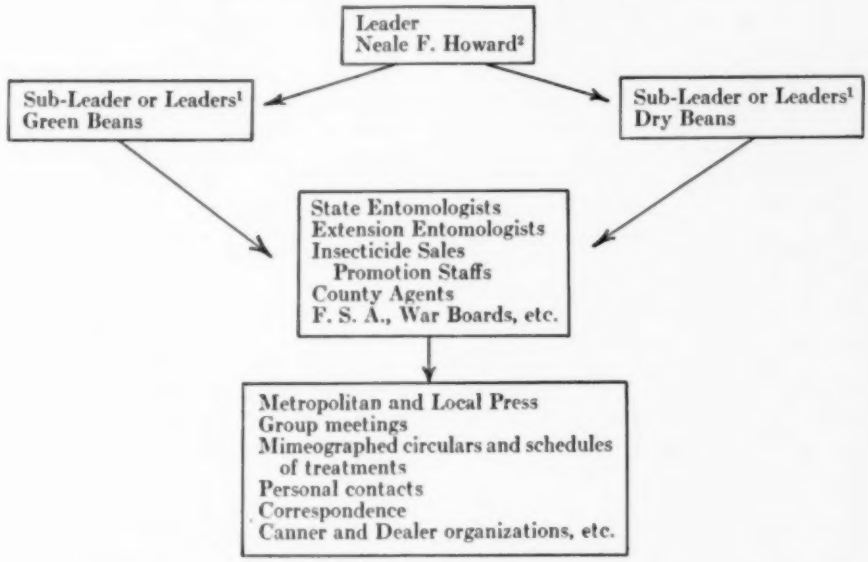
The nature of the assignment of many entomologists who are not involved directly in the war production goals may seem to leave them out of this cooperative endeavor, but their help is solicited by the committee and they are urged to offer their help to the leaders who will be requested to serve. In addition, there are manifold opportunities for such entomologists to organize their own cooperative endeavors with others working in the same or closely allied fields. The Committee would like to be informed of such action.

The goals in the lumber business are closely tied up with the work that the Bureau is doing in forest insects and therefore it does not seem desirable at this time to appoint any leaders in this field. Likewise, since grasshopper work is completely organized on a nation-wide basis, with Claude Wakeland as the leader, there seems to be no necessity for further organization. This is true of other large-scale control projects as well.

This situation presents to economic entomology the greatest opportunity in all its history to prove its worth and to demonstrate its merit as a means of conserving for human benefit the things which man needs for his livelihood. If economic entomology meets this challenge, it will build for us a greater future of usefulness and will make of the profession an ever greater force for human welfare. This challenge is then to each of us, and each must discover how best he can meet it.

Respectfully yours,
Committee on Coordination of
Entomology with the War Effort:
E. F. PHILLIPS, *Chairman*
ERNEST N. CORY
J. S. HOUSER
AVERY S. HOYT
L. M. PEAIRS
P. D. SANDERS
F. N. WALLACE, and
H. B. WEISS, *President*

SUGGESTED CHART OF THE ORGANIZATION TO IMPLEMENT COOPERATION ON INSECT CONTROL FOR ATTAINING THE PRODUCTION GOALS
Canning and Dry Beans—Goals—100% and 113%



[1] To be selected by leader.
[2] Other leaders may find it desirable to appoint their subleaders on a regional basis, a crop basis, or on a specific insect pest basis.